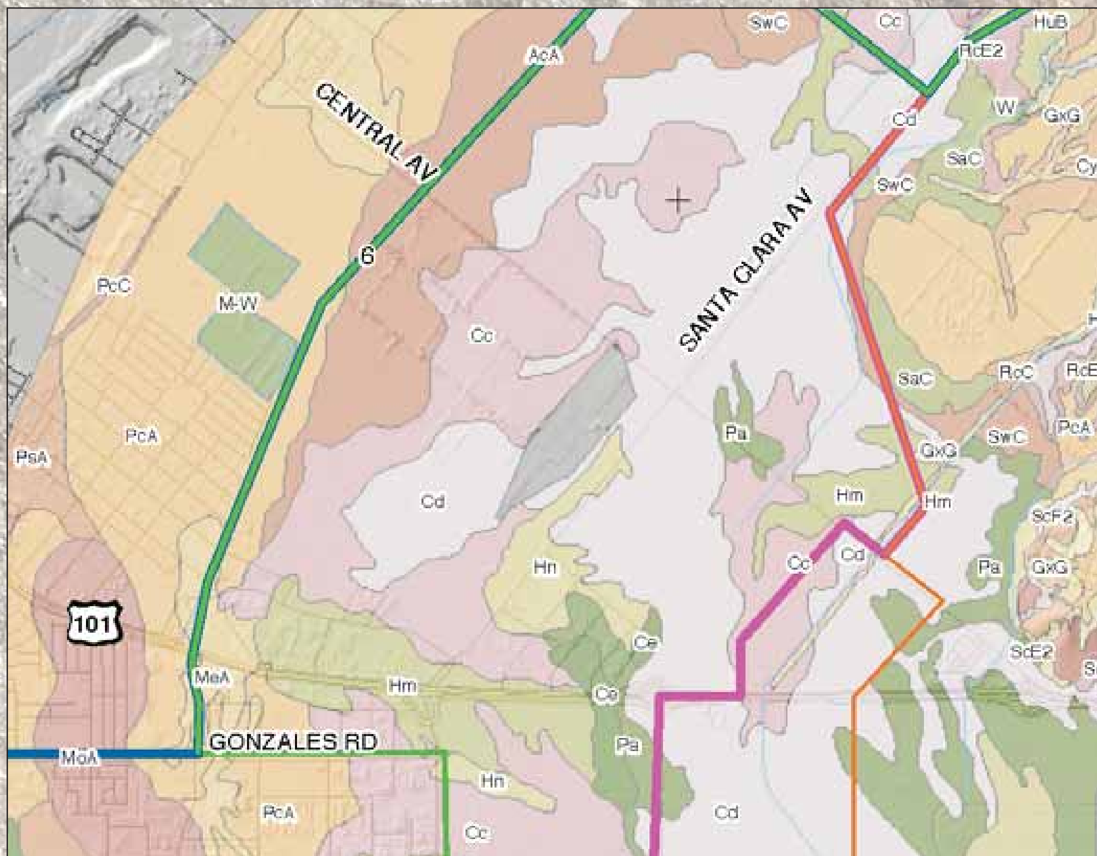
Appendix J3
Geologic and Geotechnical Evaluation of Proposed Pipeline Routes

WILLIAM LETTIS & ASSOCIATES, INC.

Geologic and Geotechnical Evaluation of Proposed Center Road and Line 225 Loop Pipeline Routes for BHP Cabrillo Port Project Ventura and Los Angeles Counties, California



Submitted to:
Southern California Gas Company
Los Angeles, CA 90051

Submitted by:
William Lettis & Associates, Inc.
1777 Botelho Drive, Suite 262
Walnut Creek, CA 94596

May 2005

WLA

WILLIAM LETTIS & ASSOCIATES, INC.

1777 Botelho Drive, Suite 262, Walnut Creek, California 94596
tel (925) 256-6070 fax (925) 256-6076

May 25, 2005

Mr. Rick Gailing
Southern California Gas Company
Box 513249, GT 24H3
Los Angeles, CA 90051-1249

RE: Copies of Final SoCalGas Geotechnical Report, "*Geologic and Geotechnical Evaluation of Proposed Center Road and Line 225 Loop Pipeline Routes for BHP Cabrillo Port Project, Ventura and Los Angeles Counties, California*"

Dear Mr. Gailing:

William Lettis & Associates, Inc. (WLA) is pleased to provide SoCalGas with the enclosed revised Final Geotechnical Report on the proposed Center Road and Line 225 Loop pipeline routes in Ventura and Los Angeles Counties for the BHP Cabrillo Port Project. This comprehensive report discusses existing geologic conditions along the proposed routes, identifies and characterizes geologic and seismic hazards, and provides information on possible design and construction considerations.

We appreciate the opportunity to assist SoCalGas in this important project. If you have any questions, please do not hesitate to call me at (925) 256-6070 or Scott Lindvall at (661) 775-4990.

Sincerely,
WILLIAM LETTIS & ASSOCIATES, INC.

Christopher Hitchcock, C.E.G. 2017
Senior Geologist

REGISTERED GEOLOGIST
CHRISTOPHER S. HITCHCOCK
No. 2017
CERTIFIED ENGINEERING GEOLOGIST
STATE OF CALIFORNIA

Geologic and Geotechnical Evaluation of Proposed Center Road and Line 225 Loop Pipeline Routes for BHP Cabrillo Port Project Ventura and Los Angeles Counties, California

Submitted to:
Southern California Gas Company
Box 513249/ML 24H3
Los Angeles, CA 90051

By:
William Lettis & Associates, Inc.
1777 Botelho Drive, Suite 262
Walnut Creek, CA 94596

May 25, 2005

TABLE OF CONTENTS

1.0 INTRODUCTION 1
1.1 Location of Pipeline Routes 2
1.2 Scope of Work 3
2.0 REGIONAL GEOLOGIC SETTING 4
2.1 Regional Seismicity 4
3.0 Pipeline Route Description and Conditions 8
3.1 Geologic Deposits 8
3.1.1 Geologic Deposits along Center Road Pipeline Routes 8
3.1.2 Geology along Line 225 Loop Pipeline Routes 9
3.2 Soils along Proposed Pipeline Routes 12
3.2.1 Soil Conditions along the Proposed Center Road Pipeline Routes 13
3.2.2 Soil Conditions along the Proposed Line 225 Loop Routes 20
3.3 Groundwater Conditions 24
3.3.1 Depth to Groundwater along the Center Road Pipeline Routes 24
3.3.2 Depth to Groundwater along the Line 225 Loop Routes 25
4.0 GEOLOGIC HAZARDS 27
4.1 Fault Rupture 27
4.1.1 Wright Road Fault 28
4.1.2 Holser Fault 29
4.2 Ground Shaking 30
4.3 Liquefaction Hazard 31
4.3.1 Liquefaction Susceptibility 32
4.3.2 Liquefaction Opportunity 32
4.3.3 Liquefaction Potential 32
4.3.4 Liquefaction Surface Effects 33
4.4 Ground Subsidence 36
4.5 Slope Stability 37
4.6 Tsunamis/Seiche 37
4.7 Flooding and Erosion Hazards 38
4.8 Expansive and Collapsible Soils 38

4.9 Corrosive Soils ... 39
5.0 PIPELINE CONSTRUCTABILITY ... 42
5.1 Trench Stability ... 42
5.2 Potential Dewatering Requirements ... 42
5.3 Backfill Requirements ... 42
6.0 SUMMARY AND RECOMMENDATIONS ... 43
7.0 REFERENCES ... 45

LIST OF TABLES

Table 1. Known Active and Potentially Active Faults within 50 mile (100 km) Radius. ... 6
Table 2. Recorded Earthquakes >6.0 Magnitude within 25 mile (40 km) of the Pipeline Routes and Large Earthquakes within ~80 miles (129 km), 1800 to 2004. ... 7
Table 3. Geologic Deposits along the Center Road Pipeline Routes. ... 10
Table 4. Geologic Deposits along Line 225 Loop Primary and Secondary Routes. ... 12
Table 5. Description of Soils along Center Road Pipeline Routes. ... 14
Table 6. Description of Soils along Line 225 Loop Pipeline Routes. ... 21
Table 7. Liquefaction Susceptibility for Geologic Units along Center Road Pipeline Routes. ... 34
Table 8. Summary Table of Potentially Expansive Soils along All Pipeline Routes. ... 40
Table 9. Summary Table of Steel (uncoated) Corrosion Hazard along All Pipeline Routes. ... 41

LIST OF FIGURES

Figure 1. Regional Fault Map
Figure 2. Location of Proposed Center Road Pipeline Routes
Figure 3. Location of Proposed Line 225 Loop Routes
Figure 4. Geologic Map of Proposed Center Road Pipeline Routes
Figure 5. Geologic Map of Proposed Line 225 Loop Routes
Figure 6. Soils Map of Proposed Center Road Pipeline Routes
Figure 7. Soils Map of Proposed Center Road Pipeline Routes showing USCS Classifications
Figure 8. Soils Map of Proposed Line 225 Loop Routes

Figure 9. Soils Map of Proposed Line 225 Loop Routes showing USCS Classifications

Figure 10. Map of Depth to Groundwater along Center Road Pipeline Routes

Figure 11. Map of Depth to Groundwater along Line 225 Loop Routes

Figure 12. Map of Faults and Ground Motion Contours along Center Road Pipeline Routes

Figure 13. Map of Active Faults along Center Road Pipeline Routes

Figure 14. Map of faults and ground motion contours along Line 225 Loop Pipeline Routes

Figure 15. CGS Landslide and Liquefaction Hazard Zones for Center Road Pipeline Routes

Figure 16. Liquefaction Susceptibility Mapping and Boreholes for Center Road Pipeline

Figure 17. Liquefaction Susceptibility Mapping for Line 225 Loop Pipeline Routes

Figure 18. CGS Landslide and Liquefaction Hazard Zones for Line 225 Loop Pipeline Routes

Figure 19. Flood Hazard Zones for Center Road Pipeline Routes

Figure 20. Flood Hazard Zones for Line 225 Loop Routes

Figure 21. Soil Corrosivity Maps for Center Road Pipeline Routes

Figure 22. Soil Corrosivity Maps for Line 225 Loop Routes

1.0 INTRODUCTION

This report presents the results of the William Lettis & Associates, Inc. (WLA) geologic and geotechnical evaluation of existing conditions, potential geologic hazards, and possible construction constraints along the proposed Center Road Pipeline routes that connect the BHP Cabrillo Port with SoCalGas Center Road Station, in the vicinity of Oxnard, and Line 225 Loop Pipeline routes, in the Santa Clarita Valley, California (Figure 1). In this report, we describe geologic, geotechnical, and hydrological conditions along the proposed pipeline routes based on review of regional geologic data and maps, scientific papers, site-specific geotechnical reports, and recent fault rupture and seismic hazard (liquefaction and landslide) regulatory maps prepared by the California Geological Survey. No field investigations or site reconnaissance were conducted as part of this study. Our review of existing conditions and potential geologic hazards was completed in conformance with applicable codes and regulations including the California Seismic Hazards Mapping Act and California Building Code (CBC) Title 24, Part 2, Volumes 1 and 2.

Our assessment includes evaluation of potential geologic hazards, including the potential for surface fault rupture, strong ground shaking, and seismically-induced liquefaction along the proposed pipeline routes. Liquefaction is a process whereby earthquake strong ground shaking transforms granular material from a solid state into a liquefied state, resulting in reduced bearing strength. This subsurface process can cause ground deformation at the surface, including differential settlement and lateral spreading. Differential settlement caused by liquefaction can impact buried pipelines but generally does not pose a rupture hazard for modern steel pipelines (O'Rourke and Liu, 1999). However, lateral spreading of stream banks caused by liquefaction may pose a potential localized hazard to a pipeline, if the associated surface offset is large enough, because lateral spreads can produce compressional loads.

Because recent regulatory mapping of liquefaction hazard by the California Geological Survey (CGS) shows the presence of liquefaction hazard along much of the Center Road and Line 225 Loop Pipeline routes (CGS, 1997; 2002), we evaluate and discuss possible liquefaction-related impacts for these routes in accordance with the California Seismic Hazards Mapping Act of 1990. As specified in CGS Special Publication 117 (1997), our investigation of potential seismic hazards along the proposed pipeline routes included a comprehensive screening evaluation of liquefaction and landslide hazards. Based on results of our liquefaction hazard screening, we performed quantitative liquefaction analyses of selected borings compiled from existing geotechnical reports within areas of potentially moderate to high liquefaction hazard within Seismic Hazard Special Study areas zoned by the State of California. The boring logs used in our analyses are available upon request. The scope of our evaluation of liquefaction and other seismic hazards did not include subsurface exploration of the pipeline routes by our firm.

1.1 Location of Pipeline Routes

The proposed new Center Road Pipeline in the vicinity of Oxnard, Ventura County extends northward from near Port Hueneme at the coast across the relatively flat Oxnard Plain (Figure 1). The six proposed pipeline routes extend northward along Nauman and Del Norte Boulevard (Proposed Route 1), Wolff Road (Route 2), Rice Road (Route 3), the Point Mugu Shore Crossing (Route 4), Arnold Road (5), and eastward along Gonzales Road, and then north along Rose Avenue under Highway 101 (Route 6; Figure 2). From Highway 101, the pipeline routes extends along agricultural roads and fields to Santa Clara Avenue, up La Vista Avenue, and terminate at the intersection of Center Road and La Vista Avenue (Figure 2).

The proposed new loop pipeline in Santa Clarita, Los Angeles County (Line 225 Loop), would generally parallel existing Line 225. The proposed new Line 225 Loop Primary pipeline route extends southeast across Rye Canyon Road, northeast along Avenue Stanford, southeast along Avenue Scott where it crosses San Francisquito Creek along the Avenue Scott Bridge. It then continues south along McBean Parkway, crosses the main Santa Clara River on the McBean Parkway Bridge, and then follows Magic Mountain Parkway east and spans the South Fork of the Santa Clara River on the Magic Mountain Bridge. At San Fernando Road the pipeline continues south before extending east along secondary roads into the hills (Figure 3). At the San Francisquito Creek and Santa Clara River crossings, the pipeline will be attached to the underside of the existing open-girder bridges at Avenue Scott and McBean Parkway. At the South Fork of the Santa Clara River crossing, the pipeline will be installed within the roadway through the existing bridge. No access or other work will be necessary within or underneath the channel or banks of the river.

The proposed Line 225 Loop Secondary route deviates from the Primary route at Avenue Stanford where it extends southward across the Santa Clara River and east along Magic Mountain Parkway before joining the primary route at the intersection of McBean and Magic Mountain Parkways. The pipeline is planned to cross the Santa Clara River using either the existing pipe bridge or an open cut.

1.2 Scope of Work

Our investigation included a review of relevant topographic, geologic and soils engineering maps and reports, aerial photographs, groundwater contour maps, the history of liquefaction in the area, and other relevant published and unpublished reports. Our evaluation included the following scope of work:

1) Review of existing geotechnical reports, geologic maps, groundwater and soil maps, and regional seismic and geologic data;
2) Identification of potential geologic hazards along the pipeline route;
3) Liquefaction analyses of borings within areas of possibly moderate to high liquefaction hazard using the Seed Simplified Approach (Seed et al., 1985);
4) Calculation of possible fault rupture, ground settlement, and lateral spreads along proposed pipeline routes;
5) Evaluation of potential construction constraints based on available geotechnical information and development of possible mitigations, and;
6) Preparation of this report.

This report was prepared to describe the general geologic conditions and potential geologic hazards along the proposed alternative pipeline routes based on existing published and unpublished information. In addition, we discuss possible construction constraints and mitigation alternatives to reduce potential impacts to the proposed pipelines. All tasks of this investigation were performed under the direction of Christopher S. Hitchcock, C.E.G. 2017, with review by Scott Lindvall, C.E.G. 1711, and Dr. William Lettis, C.E.G. 1296. Robert Givler and Rick Ortiz, staff geologists, assisted Mr. Hitchcock in compiling and interpreting the available geologic and geotechnical data for the proposed pipeline routes.

2.0 REGIONAL GEOLOGIC SETTING

The Center Road and Line 225 Loop Pipeline routes are located in the Transverse Ranges geomorphic province of southern California, characterized by east-west trending folds, thrust faults, and fault-bounded valleys (Figure 1). Regional uplift in the Transverse Ranges, resulting from crustal contraction across the large bend in the San Andreas fault, is accommodated by uplift of west-trending mountain ranges above major reverse faults.

The proposed routes, therefore, are located in a seismically active region with numerous nearby active strike-slip and reverse faults (Figure 1; Table 1). These fault systems include the Oak Ridge and Sierra Madre-Cucamonga fault systems, that extend from the San Andreas fault near San Bernardino to the western Santa Barbara Channel, and the Transverse Ranges Southern Boundary fault system (Dolan et al., 1995), that extends along the northern margin of the Los Angeles Basin and offshore along the Malibu Coast.

The proposed Center Road Pipeline routes extend across the Oxnard Plain, south of the Santa Clara River (Figures 1 and 2). The Oxnard Plain is a broad alluvial basin underlain by alluvial sediments, primarily alluvial fan and floodplain deposits of the Santa Clara River. Surficial deposits typically are young (Holocene through Historic age) and generally poorly consolidated. Turner (1975) documents that the thickness of Holocene deposits averages between 200 and 250 feet throughout most of the Oxnard Plain.

The proposed Line 225 Loop Primary and Secondary Pipeline routes are located in the Santa Clarita Valley, a valley located along the upper Santa Clara River and bounded on the south by foothills of the San Gabriel and Santa Susana Mountains (Figures 1 and 3). The Santa Clara River Valley is underlain by fluvial sediments that reach a maximum thickness of about 200 feet near the center of the present river channel in the Saugus area and thin towards the valley margins at the base of the bounding bedrock hills (Santa Clarita Valley Water Report, 2000).

2.1 Regional Seismicity

Faults in the vicinity of the proposed pipeline routes have produced several major historic earthquakes (Table 2; Weber and Kiessling, 1975, 1978; Toppozada et al., 2000). In 1812, an earthquake of about magnitude M7 occurred, probably in the Santa Barbara Channel (Ellsworth, 1990). The 1812 earthquake severely damaged the mission in Ventura (Mission San Buenaventura), and is associated with a damaging tsunami along the coastline (Townley, 1939). In 1857, the great Fort Tejon earthquake (about M8) ruptured about 200 miles of the inland San Andreas Fault, from Cholame to Wrightwood, and also severely damaged Mission San Buenaventura.

Earthquakes in the Santa Barbara Channel in 1925 (M6.3), 1941 (M5.5), and 1978 (M5.1) caused minor damage in Ventura (Bailey, 1925; Townley, 1939). The 1933 M6.4 Long Beach earthquake caused similar minor damage in the Ventura area. In 1973, an earthquake offshore of Point Mugu (M5.2) caused widespread damage in the Oxnard area, including some structural damage to buildings (Lander et al., 1973). The 1994 M6.7 Northridge earthquake caused widespread minor damage in Ventura County (Barrows et al., 1995).

Table 1. Known Active and Potentially Active Faults within 50 mile (100 km) Radius.

Fault	Approximate Distance from Center Road routes (miles)	Approximate Distance from Line 225 Loop routes (miles)	Activity	Slip-Rate (mm/yr)	Potential Rupture Length (km)	Probable Magnitudes Mw
Wright Road Fault	0	32	Holocene	unknown	4.5	unknown
Simi Fault (Camarillo and Springville Faults)	8.4	11.5	Holocene	1.0	40	6.7
Oak Ridge Fault	2.2	11.5	Holocene	4	90	6.9
Ventura Fault	4.8	32.3	Holocene	1	20	6.8
Santa Cruz Island Fault	15.3	49.6	Holocene	6.5-7.3	60	6.8
Santa Susanna Fault	20	4.2	Late Quaternary	5.0-7.0	38	6.6
San Gabriel Fault	30.9	0.3	Late Quaternary	1.0-5.0	140	7.0
San Fernando Fault	36.4	7.4	Holocene	2	17	6.7
Sierra Madre Fault	47	16.8	Holocene	3	55	7
San Andreas Fault	38.3	19.1	Holocene	20-35	550	6.8-8.0
Verdugo Fault	38.2	10.3	Holocene	0.5	21	6.7
Santa Ynez Fault	18.4	22	Late Quaternary - Holocene	2	130	7
Holser Fault	30.2	0	Late Quaternary	0.4	20	6.5
San Cayetano Fault	11.5	10	Quaternary	6	45	6.8

California Geological Survey, 1998, Maps of known active fault near-source zones in California and adjacent portions of Nevada: International Conference of Building Officials.

Table 2. Recorded Earthquakes >6.0 Magnitude within 25 mile (40 km) of the Pipeline Routes and Large Earthquakes within ~80 miles (129 km), 1800 to 2004.

Date	Estimated Magnitude	Quake Name and/or Fault Name	Distance and Direction from Project to Epicenter
12/08/1812	7.5	San Andreas Fault	~50 miles (80 km) E of Line 225 Loop
12/21/1812	7.1	Santa Barbara Channel	~36 miles (58 km) W of Center Road Pipeline routes
09/24/1827	6.0	Anacapa-Dume Fault	~8 miles (13 km) E of offshore pipeline
01/09/1857	7.9	Ft. Tejon/ San Andreas Fault	~80 miles (129 km) WNW of Center Rd. and Line 225 Loop Pipelines (Surface rupture 23 miles (37 km) from Line 225 Loop Pipelines)
06/29/1925	6.8	Santa Barbara Channel	~38 miles (61 km) W of Center Road Pipeline routes
03/11/1933	6.4	Long Beach	~60 miles (96 km) E of pipeline routes
07/01/1941	5.9	Pitas-Point Ventura Fault	~25 miles (40 km) WNW from Center Road Pipeline routes
07/21/1952	7.3	Kern County, Quake, White Wolf Fault	~45 miles (72 km) NW of Line 225 Loop Pipeline route
02/09/1971	6.6	Sylmar Quake, San Fernando Fault	~7 miles (11 km) NE of Line 225 Loop
02/21/1973	5.3	Anacapa/ Dume Fault	11 miles (18 km) SSW of Center Road Pipeline routes
08/13/1978	6.0	Santa Barbara	~33 miles (53 km) WNW of Center Road Pipeline routes
01/17/1994	6.7	Northridge Quake and Fault	~12 miles (19 km) S of Line 225 Loop Pipeline route

Earthquake data are from Toppozada et al. (2000).

3.0 PIPELINE ROUTE DESCRIPTION AND CONDITIONS

The proposed pipelines likely will be installed in trenches along paved streets in urban areas and along paved and unpaved agricultural roads elsewhere. The average depth of the pipeline likely will be less than 6 feet, from the ground surface to the top of the pipe. The proposed routes cross several major and minor drainages, including the Santa Clara River. These crossings are of particular interest as locations with potential for possible erosion, stream scour, and liquefaction-induced lateral spreading. Below we discuss geologic deposits, surficial soils, and depth to groundwater present along the proposed pipeline routes, including potential hazards at pipeline crossings of major rivers and streams.

3.1 Geologic Deposits

The following section describes the geologic units that underlie the pipeline routes for the proposed Center Road Pipeline in the vicinity of Oxnard and Line 225 Loop Primary and Secondary routes in Santa Clarita Valley. Only geologic units that likely would be encountered during construction are described below, based on review of available geologic maps and previous mapping by William Lettis & Associates, Inc. for the U.S. Geological Survey (Hitchcock et al., 2000a; 2000b).

3.1.1 Geologic Deposits along Center Road Pipeline Routes

The Center Road Pipeline routes are underlain by Holocene and historic sedimentary deposits consisting primarily of sandy material deposited in alluvial fan and stream channel (wash) depositional environments associated with the Santa Clara River (Figure 4, Hitchcock et al., 2000a; 2000b). This river-transported material primarily is derived from pre-Quaternary sandstone, sand-rich sedimentary bedrock, and older Quaternary units exposed in the highland regions of northern Ventura and western Los Angeles counties (CGS, 2002).

Most of the central portion of the primary pipeline route along Gonzales Road is underlain by historic alluvial fan (Qf) and flood deposits (Qw) derived from the Santa Clara River to the north (Figure 4). Historical deposits contain sediments likely deposited or reworked within the past 300 years based on young geomorphic features interpreted from aerial photographs and historic accounts of flooding. Historical alluvial-fan (Qf) deposits and wash deposits (Qw/Qw1) include braided stream channel deposits, sheet-flood deposits, and debris flows. Historical alluvial-fan and wash deposits are differentiated from older fan deposits by the presence of active braided channels evident in vintage aerial photographs. Stream wash deposits predominately contain poorly sorted, loose sands and gravels, with minor silt and clay. Borehole log data indicate that these young Quaternary sediments consist of alternating beds of sand, gravel, and silt locally highly susceptible to liquefaction (Table 3). Although the secondary pipeline route extends across similar deposits, the deposits are finer grained with a higher percentage of silt and clay, and thus less likely to liquefy during moderate to large earthquakes.

The northernmost portion of the proposed Center Road Pipeline routes cross Holocene and Historic alluvial-fan deposits (Qyf1, Qyf2, Qf) that contain moderately to poorly sorted sand, gravel, silt, and clay. Sediments commonly are predominantly coarse grained, consisting of well-sorted silty sand with less common clayey to poorly sorted sand. Fan deposits typically are more poorly sorted and coarse-grained than axial valley deposits (Qya2) of similar age.

At the north end of the proposed Center Road Pipeline routes, near La Vista Avenue, the pipeline traverses Pleistocene fan (Qof) and terrace deposits (Qoat2), underlain by Saugus Formation (B), that predominately are fine-grained but typically contain interbedded fine- and coarse-grained sediments (Figure 4). Coarse sediments consist of poorly- to well-sorted silty sand and gravel. Finer-grained deposits commonly consist of clay and silt. In boring log descriptions, Pleistocene deposits are identified primarily by engineering properties, including higher dry unit weight and blow counts relative to younger deposits.

3.1.2 Geology along Line 225 Loop Pipeline Routes

Geologic units along Line 225 Loop Pipeline routes are shown on Figure 4. The map is derived from Yerkes and Campbell (1995), as modified by CGS (1997b). Other geologic maps of the region reviewed for the proposed Line 225 Loop Pipeline routes include Winterer and Durham (1962), Weber (1982), Smith (1984), and Treiman (1986; 1987).

The Santa Clara River and Santa Clarita Valleys are underlain by fluvial sediments (units Qal, Figure 5, Table 4). Alluvium reaches a maximum thickness of about 200 feet near the center of the present river channel in the Saugus area and thins towards the flanks of the bedrock hills (Santa Clarita Valley Water Report, 2000). The alluvium primarily consists of stream channel and flood plain deposits ranging in age from Pleistocene at depth (Qpa) to latest Holocene at the surface (Qal). Mapped as floodplain (Qfp) by Yerkes (1996), these young alluvial deposits (mapped as Qal by CGS, 1997b) primarily consist of well-

Table 3. Geologic Deposits along the Center Road Pipeline Routes.

Proposed Route

Geologic Unit*	Pipe Length (feet)	Description	Liquefaction Susceptibility
Qw2	4,885	Modern wash deposits - unconsolidated sand and gravel	High
Qf	1,993	Modern alluvial fan deposits - gravel, sand, and silt	High to Moderate
Qya2	7,423	Holocene axial valley deposits - Silt, sand, and minor gravel	High to Moderate
Qyf2	4,185	Latest Holocene alluvial fan deposits - gravel, sand, silt and clay	High to Moderate
Qof	1,071	Pleistocene fan deposits - gravel, sand, and silt	Very Low
Qyf1	2,024	Holocene alluvial fan deposits - gravel, sand, silt and clay	Low

Center Road Pipeline Alternative 2

Geologic Unit*	Pipe Length (feet)	Description	Liquefaction Susceptibility
Qf	1,993	Modern alluvial fan deposits - gravel, sand, and silt	High to Moderate
Qw2	7,290	Modern wash deposits - unconsolidated sand and gravel	High
Qya2	4,176	Holocene axial valley deposits - Silt, clay, sand, and minor gravel	High to Moderate
Qyf2	4,185	Latest Holocene alluvial fan deposits - gravel, sand, silt and clay	High to Moderate
Qof	1,071	Pleistocene fan deposits - gravel, sand, and silt	Very Low
Qyf1	2,024	Holocene alluvial fan deposits - gravel, sand, silt and clay	Low

Center Road Pipeline Alternative 1

Geologic Unit*	Pipe Length (feet)	Description	Liquefaction Susceptibility
Qf	2,670	Modern alluvial fan deposits - gravel, sand, and silt	High to Moderate
Qw2	5,388	Modern wash deposits - unconsolidated sand and gravel	High
Qya2	10,724	Holocene axial valley deposits - Silt, clay, sand, and minor gravel	High to Moderate
Qyf2	3,999	Latest Holocene alluvial fan deposits - gravel, sand, silt and clay	High to Moderate

Center Road Pipeline Alternative 1

Geologic Unit*	Pipe Length (feet)	Description	Liquefaction Susceptibility
Qof	1,071	Pleistocene fan deposits - gravel, sand, and silt	Very Low
Qyf1	2,023	Holocene alluvial fan deposits - gravel, sand, silt and clay	Low

Point Mugu Shore Crossing

Geologic Unit*	Pipe Length (feet)	Description	Liquefaction Susceptibility
Qyf2	2,291	Latest Holocene alluvial fan deposits - gravel, sand, silt and clay	High to Moderate

Center Road Pipeline Alternative 1

Geologic Unit*	Pipe Length (feet)	Description	Liquefaction Susceptibility
Qf	2,306	Modern alluvial fan deposits - gravel, sand, and silt	High to Moderate

Santa Barbara Channel/Gonzales Road

Geologic Unit*	Pipe Length (feet)	Description	Liquefaction Susceptibility
Qf	5,701	Modern alluvial fan deposits - gravel, sand, and silt	High to Moderate
Qw2	2,271	Modern wash deposits - unconsolidated sand and gravel	High
Qya2	7,195	Holocene axial valley deposits - Silt, clay, sand, and minor gravel	High to Moderate
Qyf2	655	Latest Holocene alluvial fan deposits - gravel, sand, silt and clay	High to Moderate
Qof	1,071	Pleistocene fan deposits - gravel, sand, and silt	Very Low
Qyf1	2,024	Holocene alluvial fan deposits - gravel, sand, silt and clay	Low

* Descriptions are from Hitchcock et al. (2000a). See Figure 4 for map of geologic units along route.

Table 4. Geologic Deposits along Line 225 Loop Primary and Secondary Routes.

Primary Route

Geologic Unit*	Description	Pipe Length (feet)	Liquefaction Susceptibility
Qal	Undifferentiated alluvial deposits	9,051	Very High, High, Low
Qt	Pleistocene terrace deposits	2,823	Very Low
Qpa	Undifferentiated Pleistocene alluvium	222	Very Low
Qs	Saugus Formation bedrock	32	Very Low

Secondary Route

Geologic Unit*	Description	Pipe Length (feet)	Liquefaction Susceptibility
Qal	Undifferentiated alluvial deposits	7,701	Very High, High, Low
Qt	Pleistocene terrace deposits	3,161	Very Low
Qs	Saugus Formation bedrock	289	Very Low
Qpa	Undifferentiated Pleistocene alluvium	222	Very Low

* Descriptions are from California Geologic Survey (1997b). See Figure 5 for map of geologic units along route.

graded, fine- to coarse-grained and poorly graded, fine to coarse-grained sand. Deposits also commonly consist of gravel, often with pebbles, cobbles and boulders (CGS, 1997b).

Other materials along the pipeline routes include Pleistocene terrace deposits (Qt) preserved on hills flanking the valley and bedrock of the Saugus Formation (Qs). The Plio-Pleistocene Saugus Formation generally consists of non-marine, thinly to medium bedded, medium- to coarse-grained arkosic sandstone and pebble conglomerate, and mudstone (Dibblee, 1996).

3.2 Soils along Proposed Pipeline Routes

Soil Conservation Service (SCS) soil surveys of Ventura County (Edwards et al., 1970) and Los Angeles County (Woodruff et al., 1970) provide reasonable approximations of likely soil properties at pipeline depth for the proposed pipeline routes under consideration. Soils generally are sampled to a depth of 5 to 6 feet and, therefore, soil descriptions are limited to that depth and may not be representative of deeper soil conditions. In addition, soil surveys typically generalize soil properties and thus hazards associated with different soil types. Therefore, estimates of soil corrosivity and shrink-swell potential likely are conservative along the proposed pipeline routes.

As part of our evaluation of geologic hazards along the proposed pipeline routes, soil units within the GIS database of the routes incorporated corrosivity and shrink-swell potential engineering properties tabulated in the SCS reports. Soil corrosivity values compiled from SCS soil surveys are based on the rate uncoated steel may corrode when buried in a soil (Soil Conservation Service, 1969). These index values are derived from soil texture, drainage, acidity, and electrical conductivity data. Modern coated pipelines are much less likely to corrode under values estimated for uncoated steel by the SCS and thus these values are highly conservative. Shrink-swell potential is a relative hazard related to how changes in water content may cause expansive soils to shrink or swell, an effect that can impact pipe integrity. Index values within the soil surveys are derived from the amount and composition of clay in the soil (Edwards et al., 1970).

3.2.1 Soil Conditions along the Proposed Center Road Pipeline Routes

Soils in the Ventura region have highly variable geotechnical properties, and portions of the proposed route are underlain by soils that are clay-rich, highly plastic, have a moderate to high corrosive potential, and are potentially expansive (Edwards et al., 1970). These soils are derived from physical and chemical weathering of young alluvial deposits that cover the Oxnard plain, as shown on Figure 4.

Soil series encountered along the proposed pipeline routes include Carmarillo, Hueneme, Pacheco Huerhuero, Mocho, Rincon, Sorrento, Cropley, Anacapa soils, and Zamora (Table 5, Figure 6). Soils along the proposed primary, secondary pipeline, and the Santa Barbara Channel Alternative routes consist primarily of silty sandy, silts, silty sands, clayey silts, and lean clays that have been subdivided based on physiographic position and parent material (Figure 7; Edwards et al., 1970).

Pipeline route specific summaries of the most important soil units and associated geotechnical properties are given below. The proposed pipeline routes 1, 2, and 6 (Figure 6) cross several soil units with variable geotechnical properties. Pipeline routes 1 (Primary) and 2 (Secondary) have identical routes except north of Laguna Avenue and south of Central Avenue. South of Laguna Avenue the primary and secondary proposed pipeline routes cross the Pa, Ce, Cd, Cc, and Hn soil units (Figure 6). These soil units are composed of lean clay (CL), clayey silt (CL-ML), and silt (SM).

Table 5. Description of Soils along Center Road Pipeline Routes.

Proposed Route 1

Soil Name	Map Unit	Pipe Length (feet)	USCS Classifications	USCS Description	Steel Corrosivity	Shrink Swell Potential	Excavation Stability Hazard	Permeability
Camarillo	Cd	6,030	CL-ML,	Loam	High	Moderate	Slight	Moderate
Camarillo	Cc	1,557	SM	Sandy loam	High	Moderate	Slight	Moderately Rapid
Camarillo	Ce	3,530	CL-ML,	Loam	High	Moderate	Slight	Moderate
Hueneme	Hn	5,732	SM	Sandy loam	High	Low	Slight	Moderate to Moderately Rapid
Hueneme	Hm	715	SM	Loamy sand	High	Low	Slight	Moderate to Moderately Rapid
Pacheco	Pa	2,349	CL	Silty clay loam	High	Moderate	Slight	Moderately Slow to Rapid
Huerhuero	HuB	279	CL-ML,	Very fine sandy loam	High	Moderate	Slight	Moderately Slow to Slow
Gullied Land	GxG	205		Variable		Moderate	Severe	Variable
Rincon	RcC	94	CL	Silty clay loam	High	High	Slight	Slow to Moderately Slow
Sorrento	SwC	733	ML	Loam	High	Moderate	Slight	Moderately Slow
Anacapa	AcC	268	SM	Sandy loam	High	Low	Slight	Moderately Rpaid
Cropley	Cya	1,001	CH, CL	Clay	High	High	Slight	Slow
Garretson	GaC	226	CL-ML,	Loam	Low	Moderate	Slight	Moderate
Salinas	SaC	135	CL	Clay loam	High	Moderate	Slight	Moderately Slow
Zamora	ZmC	185	ML	Loam	High	Moderate	Slight	Moderately Slow

Center Road Pipeline Alternative 2

Soil Name	Map Unit	Pipe Length (feet)	USCS Classifications	USCS Description	Steel Corrosivity	Shrink Swell Potential	Excavation Stability Hazard	Permeability
Camarillo	Cd	6,038	CL-ML,	Loam	High	Moderate	Slight	Moderate
Camarillo	Cc	1,008	SM	Sandy loam	High	Moderate	Slight	Moderately Rapid
Camarillo	Ce	2,423	CL-ML,	Loam	High	Moderate	Slight	Moderate
Hueneme	Hn	4,777	SM	Sandy loam	High	Low	Slight	Moderate to Moderately Rapid
Hueneme	Hm	715	SM	Loamy sand	High	Low	Slight	Moderate to Moderately Rapid
Pacheco	Pa	3,848	CL	Silty clay loam	High	Moderate	Slight	Moderately Slow to Rapid
Huerhuero	HuB	279	CL-ML,	Very fine sandy loam	High	Moderate	Slight	Moderately Slow to Slow
Gullied Land	GxG	176		Variable		Moderate	Severe	Variable
Rincon	RcC	94	CL	Silty clay loam	High	High	Slight	Slow to Moderately Slow
Sorrento	SwC	733	ML	Loam	High	Moderate	Slight	Moderately Slow
Anacapa	AcC	268	SM	Sandy loam	High	Low	Slight	Moderately Rpaid
Cropley	Cya	652	CH, CL	Clay	High	High	Slight	Slow
Garretson	GaC	226	CL-ML,	Loam	Low	Moderate	Slight	Moderate
Salinas	SaC	135	CL	Clay loam	High	Moderate	Slight	Moderately Slow
Zamora	ZmC	185	ML	Loam	High	Moderate	Slight	Moderately Slow

Center Road Pipeline Alternative 1

Soil Name	Map Unit	Pipe Length (feet)	USCS Classifications	USCS Description	Steel Corrosivity	Shrink Swell Potential	Excavation Stability Hazard	Permeability
Camarillo	Cd	2,418	CL-ML,	Loam	High	Moderate	Slight	Moderate
Camarillo	Cc	2,713	SM	Sandy loam	High	Moderate	Slight	Moderately Rapid
Camarillo	Ce	766	CL-ML,	Loam	High	Moderate	Slight	Moderate
Hueneme	Hn	5,519	SM	Sandy loam	High	Low	Slight	Moderate to Moderately Rapid
Hueneme	Hm	279	SM	Loamy sand	High	Low	Slight	Moderate to Moderately Rapid
Pacheco	Pa	1,450	CL	Silty clay loam	High	Moderate	Slight	Moderately Slow to Rapid
Huerhuero	HuB	279	CL-ML,	Very fine sandy loam	High	Moderate	Slight	Moderately Slow to Slow
Gullied Land	GxG	134		Variable		Moderate	Severe	Variable
Rincon	RcC	94	CL	Silty clay loam	High	High	Slight	Slow to Moderately Slow
Sorrento	SwC	230	ML	Loam	High	Moderate	Slight	Moderately Slow
Anacapa	AcC	2,488	SM	Sandy loam	High	Low	Slight	Moderately Rpaid
Cropley	Cya	652	CH, CL	Clay	High	High	Slight	Slow
Garretson	GaC	226	CL-ML,	Loam	Low	Moderate	Slight	Moderate
Pico	PcC	581	SM	Sandy loam	High	Low	Slight	Moderately Slow
Zamora	ZmC	185	ML	Loam	High	Moderate	Slight	Moderately Slow

Point Mugu Shore Crossing/Casper Road Pipeline Route

Soil Name	Map Unit	Pipe Length (feet)	USCS Classifications	USCS Description	Steel Corrosivity	Shrink Swell Potential	Excavation Stability Hazard	Permeability
Camarillo	Cd	268	CL-ML,	Loam	High	Moderate	Slight	Moderate
Camarillo	Ce	818	CL-ML,	Loam	High	Moderate	Slight	Moderate
Hueneme	Hn	1,205	SM	Sandy loam	High	Low	Slight	Moderate to Moderately Rapid

Arnold Road Pipeline Route

Soil Name	Map Unit	Pipe Length (feet)	USCS Classifications	USCS Description	Steel Corrosivity	Shrink Swell Potential	Excavation Stability Hazard	Permeability
Camarillo	Cd	1,608	CL-ML,	Loam	High	Moderate	Slight	Moderate
Hueneme	Hn	698	SM	Sandy loam	High	Low	Slight	Moderate to Moderately Rapid

Santa Barbara Channel Alternative/Gonzales Road Pipeline Route

Soil Name	Map Unit	Pipe Length (feet)	USCS Classifications	USCS Description	Steel Corrosivity	Shrink Swell Potential	Excavation Stability Hazard	Permeability
Camarillo	Cd	634	CL-ML,	Loam	High	Moderate	Slight	Moderate
Camarillo	Cc	412	SM	Sandy loam	High	Moderate	Slight	Moderately Rapid
Hueneme	Hm	218	SM	Loamy sand	High	Low	Slight	Moderate to Moderately Rapid
Huerhuero	HuB	278	CL-ML,	Very fine sandy loam	High	Moderate	Slight	Moderately Slow to Slow
Mocho	MoA	579	CL, CL-	Loam	High	Moderate	Slight	Moderate
Gullied Land	GxG	134		Variable		Moderate	Severe	Variable
Rincon	RcC	94	CL	Silty clay loam	High	High	Slight	Slow to Moderately Slow
Sorrento	SwC	230	ML	Loam	High	Moderate	Slight	Moderately Slow
Anacapa	AcC	4,276	SM	Sandy loam	High	Low	Slight	Moderately Rpaid
Cropley	Cya	652	CH, CL	Clay	High	High	Slight	Slow
Garretson	GaC	226	CL-ML,	Loam	Low	Moderate	Slight	Moderate
Pico	PcC	581	SM	Sandy loam	High	Low	Slight	Moderately Slow
Zamora	ZmC	185	ML	Loam	High	Moderate	Slight	Moderately Slow

Between Laguna Avenue and Central Avenue the pipeline routes diverge, although the routes parallel each other and remain within a distance of 3,000 feet (Figure 3). Both alignments encounter soil units Pa, Hm, Cd, and Cc, which are primarily clayey silt (CL-ML) and minor amounts of silt (SM) and clayey silt with clay (CL-ML, CL). The alternate alignment in this section of proposed pipeline alignment two encounters clayey silt (CL-ML) and lean clay (CL) with minor amounts of silt (SM). Over all the geotechnical properties of these soils are very similar except that the shrink-swell potential of the clayey silt is moderate shrink-swell potential and the silt units have low shrink-swell potential.

North of Central Avenue proposed pipeline routes 1 and 2 encounter a wide variety of soils and moderate slopes. This reach of proposed pipelines encounters primarily soil units CyA, AcC, RcE2, HuB, with more minor amounts of ZmC, GaC, RcC, GaC, CD, and RcE2. These units consist of clayey silts, silt, lean clay, and clay. Most notable are the Cropley clay, 0 to 2% slopes (CyA), Rincon silty clay loam, 2 to 9% slopes (RcC), and Rincon silty clay loam, 15 to 30% slopes (RcE2) soil units. These soil units have high clay contents with low strength and high shrink-swell potential.

The Santa Barbara Channel Alternative/Gonzales Road pipeline route (Alignment 6) is the most distinctly different pipeline alignment (Figure 6), but is within soil units with generally uniform geotechnical properties. The reach of this proposed pipeline alignment is underlain by the AcA, PcA, and MoA soil units with minor amounts of MeA, Hm, Cd, and SwA soil units before joining pipeline Alignments 1 and 2. Pipeline Alignment 6 is underlain by silty sand (SM), with minor amounts of silt (ML), lean clay (CL), clayey silt (CL-ML). The soil units encountered along this pipeline alignment differ from the soil units encountered along the other pipeline alignments because of their higher sand-silt content and less clay content. As a result, the shrink-swell potential is low for much of Alignment 6. Alignment 3 is underlain by soil units with variable geotechnical properties along the section that joins the Primary and Secondary alignments north of Wright Road (Figure 7).

A brief description of each soil unit follows.

Cc – Camarillo sandy loam (SM), 0 to 2% slopes. The Camarillo sandy loam (Cc) is composed of predominately silty sand (SM) and is mapped on poorly drained level alluvial plains derived from primarily sedimentary rock (Figures 6 and 7). This calcareous silty sand (SM) is grayish-brown 24 inches from the surface. This soil is underlain by a 20 inch thick grayish-brown and pale-brown sandy clay loam or silty clay (CL-ML). At 44 inches deep, roughly the depth of the proposed pipeline, the soil consists of a light-gray, mottled, calcareous, stratified silty to clayey sand (SM to SC) and locally fine sand. The permeability of the soil is moderate, the surface runoff is slow, and there is minimal hazard of soil erosion.

Cd – Camarillo loam, 0 to 2% slopes. The Camarillo Loam (Cd) is mapped on poorly drained terraces and alluvial fans (Figures 6 and 7) and is composed of grayish- brown sandy loam or silty clay (CL-ML) throughout the entire soil profile. The permeability of the soil is moderate, surface runoff is slow, and there is minimal hazard of soil erosion.

Ce – Camarillo loam, sandy substratum, 0 to 2% slopes. The Camarillo loam (Ce) is composed of silty clay (CL-ML) found on the poorly drained alluvial plain (Figure 6 and 7) and is derived from sedimentary rock. Different than the from Camarillo sandy loam (Cc) soil unit, this soil is a silty clay (CL-ML) to depth of 40-48 inches and in underlain by sand. The permeability of the soil is moderate, and the surface runoff is slow. There is minimal hazard of soil erosion.

Hn – Hueneme sandy loam (SM), 0 to 2% slopes. The Hueneme sandy loam (Hn) is composed of sandy loam or silty sand (SM) and is mapped on the poorly drained alluvial plain (Figures 6 and 7). Above 17 inches deep, the soil unit is composed of grayish-brown, calcareous loamy fine sandy or silty sand (SM). Beneath this unit are layers of mottled grayish-brown and light-gray, calcareous sandy silt (ML), silty sand (SM), and sand (SW). At 65 inches depth, the soil consists of a mottled light brownish-gray calcareous silt (ML) and sand (SW). The permeability of the soil is moderately rapid and the surface runoff is very slow. The erosion hazard for this soil unit is minimal. The shrink-swell potential for this unit is low.

Hm – Hueneme loamy sand, loamy substratum (SM), 0 to 2% slopes. The Hueneme loamy sand (Hm) is composed of sandy loam or silty sand (SM) and is mapped on the poorly drained alluvial plain (Figures 6 and 7). This unit is silty sand (SM) to a depth of 40 inches. Below this depth, the unit is composed of stratified sandy silt, silty sandy (SM), and silt (ML). The permeability of the soil is moderately rapid and the surface runoff is very slow. The erosion hazard for this soil unit is minimal. The shrink-swell potential for this unit is low.

Pa – Pacheco silty clay loam (CL), 0 to 2% slopes. The Pacheco silty clay loam (Pa) is lean clay (CL) greater than 5 feet deep and is mapped on poorly drained alluvial plains (Figures 6 and 7). Above 17 inches depth this unit is composed of dark-gray, mildly alkaline to strongly alkaline lean clay (CL). The base of this upper unit becomes calcareous. Below this unit is a light brownish-gray, mottled, calcareous lean clay (CL) that is approximately 29 inches thick. Below 46 inches depth is a pale-yellow, calcareous silt (ML) and sand (SW). The permeability of this soil is moderately slow and the surface runoff is very slow. The erosion hazard for this soil is minimal.

<u>HuB – Huerhuero very fine sandy loam (CL-ML), 0 to 2% slopes</u>. The Huerhuero very fine sandy loam (HuB) is composed of silty clay (CL-ML) and is mapped on moderately well drained alluvial fans and terraces (Figures 6 and 7). Above 21 inches from the surface the soil is grayish-brown and dark grayish-brown, slightly acidic silty clay (CL-ML). Below this unit is a gray, medium acid very fine sandy loam or silt (ML), which is approximately 4 inches thick. A brown and pale-brown neutral to moderately alkaline lean clay (CL) and sandy clay loam (or clayey silt CL-ML) compose a subsoil, which is below the previous two units down to approximately 48 inches deep. The permeability of this soil is very slow, surface runoff is slow, and the erosion hazard of this soil is minimal. Shrink-swell potential is moderate.

<u>HuD2 – Huerhuero very fine sandy loam (CL-ML), 9 to 15% slopes eroded</u>. The Huerhuero very fine sandy loam (HuD2) is composed of silty clay (CL-ML) and is mapped on gently rolling terraces. This unit is 12 to 24 inches thick, moderately eroded, and has small gullies locally. The permeability of this soil is moderately slow to slow and the surface runoff is medium to rapid. This soil has a moderate to severe hazard of soil erosion.

<u>MoA – Mocho loam (CL), 0 to 2% slopes</u>. The Mocho loam (MoA) is composed of silty-clay (CL-ML) and is mapped on well-drained alluvial plains and fans (Figures 6 and 7). Above 16 inches deep this unit is composed of grayish-brown, calcareous silty clay (CL-ML). Below this unit to a depth of greater than 5 feet is grayish-brown and light brownish-gray, calcareous silty clay (CL-ML). This unit has moderate permeability, surface runoff is slow, and the hazard of soil erosion is minimal. Shrink-swell potential is moderate.

<u>CnB – Coastal Beaches</u>. The Coastal beaches soil unit (CnB) consists of narrow sandy beaches and sand dunes. This map unit includes some cobbly deposits and areas of Riverwash and Tidal flats (Figures 6 and 7). These areas are essentially barren with almost no soil development. Permeability is very rapid and surface runoff is slow. This unit is severely susceptible to erosion by wind and wave action. The

grouping of Riverwash and Tidal flats in this map unit may result in a large variability in grain size within this soil unit and a potentially significant difference in strength and stability.

GxG – Gullied Land. The Gullied Land (GxG) soil unit consists of a thin mantle (0-1 foot thick) of relatively unstable and is mapped on steep to very steep escarpments and deep gullies (Figure 2). This unit produces a large amount of silt and debris and is derived from soft sedimentary and basic igneous rocks. There is very little brush on the Gullied Land. This unit has a very high runoff and the hazard of soil erosion is very severe.

RcC – Rincon silty clay loam (CL), 2 to 9% slopes. The Rincon silty clay loam (RcC) consists of lean clay (CL) and is mapped on well-drained old alluvial fans and terraces (Figures 6 and 7). This unit consists of dark-gray, slightly acidic lean clay (CL), which is approximately 16 inches thick. Below this unit to a depth of 50 inches, approximately pipeline depth, is a dark grayish-brown and brown, neutral to moderately alkaline lean clay (CL) and clayey sand (SC) to lean clay (CL). The permeability of this unit is slow, surface runoff is medium, and the hazard of soil erosion is slight to moderate.

RcE3 – Rincon silty clay loam (CL), 9 to 30% slopes. The Rincon silty clay loam (RcE3) consists of lean clay (CL) and is mapped on well-drained old alluvial fans and terraces. This is similar to the Rincon silty clay loam (RcC), but is formed on steeper slopes, ranging from 9 to 30%. This unit is <16 inches thick and is highly susceptible to erosion hazard. Over 60% of the original soil has been removed by erosion. Within the map unit are numerous deep gullies. The permeability of this unit is slow to moderate, surface runoff is medium to rapid, and the hazard of soil erosion is severe. The shrink-swell potential is high.

SwA – Sorrento loam (ML), 0 to 2% slopes. The Sorrento loam (SwA) on 2 to 9 percent slopes consists of a 60-inch deep silt (ML) deposit and is mapped on well-drained alluvial fans and plains. This unit is grayish-brown, neutral and mildly alkaline silt. The permeability of this unit is moderate and the surface runoff is slow. There is minimal hazard of soil erosion.

SwC – Sorrento loam (ML), 2 to 9% slopes. The Sorrento loam (SwC) consists of a 60-inch deep silt (ML) deposit and is mapped on well-drained alluvial fans and plains. This unit was subdivided from the Sorrento loam (SwA) because of the gentle to moderate slopes it is mapped on. The permeability of this unit is moderate to slow and the surface runoff is medium. This unit has a slight hazard of soil erosion.

<u>PsA – Pico sandy loam (SM), 0 to 2% slopes</u>. The Pico sandy loam (PsA) consists of silty sand (SM) and is mapped on well-drained to excessively drained alluvial fans and plains. From the surface to approximately 14 inches deep the unit is grayish-brown, calcareous silty sandy (SM). Below this depth to 54 inches depth is a light brownish-gray, calcareous silt (ML) and silty sandy (SM). Below this unit is pale brown coarse sand with gravel (SP). The permeability of this unit is moderately rapid, surface runoff is slow, and there is minimal hazard of soil erosion. The shrink-swell potential for this unit is low.

<u>PcC – Pico sandy loam (SM), 2 to 9% slopes</u>. The Pico sandy loam (PcC) is similar to the Pico sandy loam, 0 to 2% slopes, but is developed on moderately inclined alluvial fans (slopes of 2 to 9%).

<u>AcA – Anacapa sandy loam (SM), 0 to 2% slopes</u>. The Anacapa sandy loam (AcA) consists of silty sand (SM) and is mapped on well-drained nearly level alluvial fans and alluvial plains (Figures 6 and 7). From the surface to a depth of 35 inches the unit is grayish-brown, neutral to mildly alkaline silt. Below this unit is a grayish-brown moderately alkaline, calcareous silty sandy (SM). This unit has moderately rapid permeability, surface runoff is slow, and the hazard of soil erosion is minimal. The shrink-swell potential of this unit is low.

<u>AcC – Anacapa sandy loam (SM), 2 to 9% slopes</u>. The Anacapa sandy loam (AcC) consists of silty sand (SM) and is mapped on well-drained moderately sloping alluvial fans (Figures 6 and 7). This unit was subdivided from the Anacapa sandy loam (AcA) because this unit was mapped on slightly inclined slopes. The permeability of this unit is moderately rapid, surface runoff is slow, and the hazard of soil erosion is slight to moderate.

<u>MeA – Metz loamy sand (SM), 0 to 2% slopes</u>. The Metz loamy sand (MeA) consists of silty sand (SM) and is mapped on excessively drained alluvial plains and fans (Figures 6 and 7). The soil consists of light brownish-gray calcareous sand (SP) and sandy silt (SM). The shrink-swell potential is low.

<u>GaC – Garretson loam (CL-ML), 2 to 9% slopes</u>. The Garretson loam consists of predominately silty-clay (CL-ML) and is mapped on well-drained alluvial fans (Figures 6 and 7). From the surface to 35 inches depth is a grayish-brown and yellowish-brown slightly acid silty-clay (CL-ML). This unit is underlain by yellowish-brown and pale-brown mildly alkaline silty sand (SM), which extends to a depth of greater than 60 inches. The permeability of this unit is moderate and the hazard of soil erosion is slight to moderate. Shrink-swell potential is moderate.

<u>Cya – Cropley clay (CH, CL), 0 to 2% slopes</u>. The Cropley clay (Cya) soil unit is composed of lean clay (CL) and fat clay (CH) and is mapped on well-drained alluvial fans and plains (Figures 6 and 7). From the ground surface to a depth of 22 inches is very dark gray, neutral and mildly alkaline lean clay to fat clay. This unit is underlain by stratified very dark grayish-brown, strongly calcareous clay, silty clay loam and silt loam, which extends to a depth of greater than 5 feet (i.e., below design depth). This unit has slow permeability, slow runoff, and only minimal hazard of soil erosion.

<u>ZmC – Zamora loam (ML), 2 to 9% slopes</u>. The Zamora loam (ZmC) is composed of silt (ML) with a clayey subsoil and is mapped on well-drain alluvial fans and benches (Figures 6 and 7). The upper most 17 inches of this soil unit consists of dark grayish-brown and brown, slightly acid and neutral silt (ML). This unit is underlain by 23 inches of brown neutral lean clay (CL). From 40 to 60 inches depth is pale-brown mildly alkaline silty sand (SM). The permeability of this unit is moderately slow, runoff is slow to medium, and the soil erosion hazard is slight. Shrink-swell potential is moderate.

<u>SaC – Salinas clay loam (CL), 2 to 9% slopes</u>. The Salinas clay loam (SaC) soil unit consists of lean clay (CL) and is mapped on well-drained alluvial fans and plains (Figures 6 and 7). The upper 26 inches of this soil unit is dark-gray neutral lean clay (CL). This unit is underlain by dark-gray to yellowish-brown to light yellowish brown calcareous lean clay (CL) and silt (ML) to a depth of 5 feet. Below 40 inches the unit becomes stratified silty sand (SM). Shrink-well potential is moderate.

<u>3.2.2 Soil Conditions along the Proposed Line 225 Loop Routes</u>

Soils along the proposed Line 225 Loop Pipeline Primary and Secondary routes consist primarily of silts, silty sands, clayey silts, and lean clays that have been mapped based on physiographic position and parent material (Figure 8; Woodruff et al., 1970). Soils in the Santa Clarita region have highly variable geotechnical properties, moderate to high corrosive potential, and are potentially expansive (Figure 9; Woodruff et al., 1970). Soils present along the proposed pipeline routes include Hanford, Yolo, Ojai, Sorrento, Mocho, Metz, and Castaic soil series (Table 6).

Table 6. Description of Soils along Line 225 Loop Pipeline Routes.

Primary Pipeline Route

Soil Name	Map Unit	Pipe Length (feet)	USCS Classification	USCS Description	Uncoated Steel Corrosivity	Shrink-Swell Potential
Hanford	HcA	8,646	SM	Sandy loam	Low	Low
Yolo	YoA	6,658	CL-ML, ML	Loam	Low	Moderate
Ojai	OgF	6,574	ML	Loam	Moderate	Low
Sandy alluvial	Sa	4,881	SM	Sand	High	-
Sorrento	SsA	3,974	ML	Loam	High	Moderate
Mocho	MoA	3,226	SC-SM, SM	Sandy loam	High	Low*
Ojai	OgE	1,860	ML	Loam	Moderate	Low
Ojai	OgC	1,841	ML	Loam	Moderate	Low
Hanford	HcC	1,379	SM	Sandy loam	Low	Low
	Rg	325	SP, SP-SM, SW	Sand		-
Metz	MgB	249	ML, SM	Loam	High	Low*
Metz	MfA	154	SM	Loamy sand	High	Low*
Castaic	CmF2	22	ML	Silty clay loam	High	Moderate

Secondary Pipeline Route

Soil Name	Map Unit	Pipe Length (feet)	USCS Classification	USCS Description	Uncoated Steel Corrosivity	Shrink Swell Potential
Yolo	YoA	24,087	CL-ML, ML	Loam	Low	Moderate
Ojai	OgF	6,575	ML	Loam	Moderate	Low
Hanford	HcA	6,566	SM	Sandy loam	Low	Low
Sorrento	SsA	6,276	ML	Loam	High	Moderate
Mocho	MoA	2,231	SC-SM, SM	Sandy loam	High	Low*
Ojai	OgE	1,860	ML	Loam	Moderate	Low
Ojai	OgC	1,842	ML	Loam	Moderate	Low
Sandy alluvial	Sa	1,433	SM	Sand	High	-
Hanford	HcC	1,339	SM	Sandy loam	Low	Low
Zamora	ZaC	1,122	ML	Loam	High	Moderate
	TsF	622		Variable		-
	Rg	328	SP, SP-SM, SW	Sand		-
Metz	MgB	249	ML, SM	Loam	High	Low*
Mocho	MpA	147	CL, CL-ML	Loam	High	Low*
Castaic	CmF2	22	ML	Silty clay loam	High	Moderate

Below is a brief description of each soil unit including geotechnical properties and potential engineering limitations associated with each soil.

<u>HcA – Hanford Sandy Loam (SM), 0 to 2% slopes</u>. The Hanford sandy loam (HcA) is composed of predominately silty sand (SM) and is underlain by a light-yellowish-brown poorly graded sand (SP) with gravel and developed on well to excessively drained level granitic alluvial fans (Figures 7 and 9). The permeability of this unit is moderately rapid. The surface runoff is slow and there is minimal hazard of soil erosion. The shrink-swell potential of this soil is low.

<u>HcC – Hanford sandy loam (SM), 2 to 9% slopes</u>. The Hanford sandy loam (HcC) is composed of predominately silty sand (SM) developed on well drained alluvial fans (Figures 7 and 9). This silty sand is similar to the Handford Sandy Loam, 0 to 2% slopes, soil unit, but is formed on 2 to 9% slopes. Runoff is slow to medium and the hazard of soil erosion is minimal to moderate. Permeability of this unit is moderately rapid.

<u>YoA – Yolo loam (CL-ML), 0 to 2% slopes</u>. The Yolo loam (YoA) is composed of predominately clayey-silt (CL-ML) and is developed on well-drained alluvial fans (Figures 7 and 9). Permeability of the Yolo loam soil unit is moderate and surface runoff is very slow. The hazard of soil erosion is minimal. Shrink-swell potential is moderate.

<u>OgC – Ojai loam (ML), 2 to 9% slopes</u>. The Ojai loam (OgC) is composed of silt (ML) and clayey silt (CL-ML) developed on well-drained terraces and foothills near Saugus (Figures 7 and 9). The permeability of this soil unit is moderately slow and runoff is medium. The soil erosion hazard is slight to moderate. The shrink-swell potential of this unit is low.

<u>OgE – Ojai loam (ML), 15 to 30% slopes</u>. The Ojai loam (OgE) is composed of predominately silt and is mapped on well-drained foothills near Solemint (Figures 7 and 9). This soil unit is similar to the Ojai Loam (OgC), but is formed on steeper slopes (15 to 30% slopes). Associated runoff and soil erosion hazard is moderate. The shrink-swell potential of this unit is low.

<u>OgF – Ojai loam (ML), 30 to 50% slopes</u>. The Ojai loam (OgF) on slopes of 30 to 50 degrees composed of silt (ML) and is mapped on well-drained steep foothills (Figures 7 and 9). This soil unit is similar to the Ojai Loam (OgC), but is formed on steeper slopes (30 to 50% slopes). The runoff for this soil unit is rapid and the hazard of erosion is high.

<u>Sa – Sandy alluvial land (SM)</u>. The sandy alluvial land soil unit (Sa) is composed of predominately silty sand (SM) and is located within the active channel of the Santa Clara River and nearby tributaries (Figures 7 and 9). This unit is composed of unconsolidated silty sand (SM) and sand (SW). This soil unit is flooded frequently and alluvial material is commonly mobilized during floods (e.g., deposited and/or eroded).

<u>SsA – Sorrento loam (ML), 2 to 5% slopes</u>. The Sorrento loam (SsA) soil unit is composed of predominately silt and is formed on well-drained alluvial fans along the Santa Clara River (Figures 7 and 9). The permeability of this soil is moderate, runoff is very slow, and the soil erosion hazard is minimal. Shrink-swell potential is moderate (Edwards et al., 1970).

<u>MoA – Mocho loam (CL), 0 to 2% slopes</u>. The Mocho loam (MoA) is composed of silty-clay (CL-ML) developed on well-drained alluvial plains and fans (Figures 7 and 9). This unit has moderate permeability, minimal soil erosion hazard and surface runoff is slow.

<u>Rg – Riverwash (SP, SP-SW, SM)</u>. The Riverwash soil unit (Rg) is composed of predominately poorly to well-graded sand (SP-SW) and silty sand (SM) and is mapped within the active channels of intermittent streams (Figures 7 and 9). The permeability of this unit is high and runoff is rapid.

<u>MfA – Metz loamy sand (SM), 0 to 2% slopes</u>. The Metz loamy sand (MfA) is composed of predominately silty sand (SM) developed on excessively drained alluvial fans. Above 7 inches deep is a brown silty sand (SM), which is underlain by brown and light-brownish-gray silty sand (SM) and sand with gravel that extends to a depth greater than 5 feet. The permeability of this soil unit is rapid, runoff is very slow, and the hazard of soil erosion is minimal.

<u>MgB – Metz loam (ML), 2 to 5% slopes</u>. The Metz loam (MgB) on slopes of 2 to 5 degrees is composed of predominately silty sand (SM) and silts (ML) developed on excessively drained alluvial fans. The permeability of this unit is rapid, runoff is slow, and the soil erosion hazard is minimal. The shrink-swell potential for this unit is low.

<u>CmF2 – Castaic-Balcom silty clay loams (ML), eroded, 30 to 50% slopes</u>. The Castaic-Balcom silty clay loam (CmF2) is composed of predominately silt and is developed on well-drained soft-shale and sandstone (Figures 7 and 9). Bedrock typically is within 36 inches of the surface. The permeability of

this unit is moderately slow and surface runoff is rapid. The hazard of soil erosion is high. Shrink-swell potential is moderate.

MpA – Mocho Loam (CL-ML), 0 to 2% slopes. The Mocho loam (MpA) is composed of predominately clayey silt (CL-ML) and is developed on moderately well-drained alluvial fans (Figures 7 and 9). The permeability of this unit is moderate and runoff is very slow. The soil erosion hazard is minimal and shrink-swell potential is moderate.

ZaC – Zamora loam (ML), 2 to 9% slopes. The Zamora loam (ZaC) is composed of predominately clayey silt (CL-ML) and is developed on well-drained old terraces (Figures 7 and 9). The permeability of this unit is moderately slow, runoff is slow to medium, and the soil erosion hazard is slight to moderate. The shrink-swell potential for this unit is moderate.

TsF – Terrace Escarpments. The Terrace escarpments (TsF) soil unit is composed of poorly graded sand (SP) developed on moderately steep to steep slopes that separate terraces from low lying alluvial plains (Figures 7 and 9). Runoff rate is moderate to rapid and the hazard of soil erosion is moderate to high.

3.3 Groundwater Conditions

Depth of groundwater below the ground surface is a significant factor governing liquefaction hazard. Saturation reduces the normal effective stress acting on loose, sandy sediments. The presence of saturated deposits, particularly in the upper 50 feet of the ground surface, significantly increases the likelihood of liquefaction and resulting potential for ground failure (Youd, 1973).

3.3.1 Depth to Groundwater along the Center Road Pipeline Routes

Groundwater conditions within the Oxnard Plain are described in reports by the California Department of Water Resources (1971), Turner (1975), Turner and Mukae (1975), Densmore (1996), and CGS (2002). Near-surface groundwater along the pipeline routes is contained in an unconfined aquifer that extends from the ground surface to a depth of about 75 feet. This semi-perched groundwater zone is separated from deeper aquifers by clayey deposits that average over 80 feet in thickness (CGS, 2002). Groundwater recharge in the Oxnard Plain originates mainly from surface and near-surface water flow of the Santa Clara River (CDWR, 1971).

Borehole logs compiled by Hitchcock et al., (2000a, 2000b) and CGS (2002) document that depth to groundwater has been consistent within the past 50 years and range from less than 5 feet to over 20 feet in depth (Figure 10). Groundwater beneath both the primary and secondary pipeline routes generally is shallow, less than 5 to 20 feet below the ground surface (Figure 10).

North of Highway 101, in the vicinity of Central Avenue, historic depth to groundwater for both pipeline routes is greater than 10 feet, and thus is unlikely to be encountered during pipeline construction (Figure 12). A portion of the Gonzales Road pipeline route is located in a zone of groundwater that is 10 to 20 feet deep, and thus shallow groundwater at the depth of the pipeline excavation is unlikely. Depth to groundwater south of Highway 101, likely is less than 10 feet for all routes and perhaps less than 5 feet near the coast. Groundwater likely will be encountered during excavation of these sections of routes south of Highway 101. Geotechnical consequences of shallow groundwater conditions include, but are not limited to, dewatering constraints during excavation/construction and potential ground instability during pipeline trenching.

3.3.2 Depth to Groundwater along the Line 225 Loop Routes

The alluvium along the Santa Clara River and its several tributaries in the Santa Clarita area serves as an unconfined alluvial aquifer system that has provided significant amounts of water for agriculture and more recently municipal water supply. The upper alluvial aquifers in Santa Clarita Valley consist primarily of stream channel and flood plain deposits of the Santa Clara River and its tributaries. Alluvium is deepest along the center of the present river channel, with a maximum thickness of about 200 feet near Saugus (Richard Slade & Associates, 1986, 2002).

Groundwater levels have varied over the period of available record (generally since the 1950s), reflecting historical changes in pumping and seasonal variations in the amount of recharge and discharge. Historic depth to groundwater data were compiled by CGS (1997b) from published groundwater investigations (Robson, 1972), annual maps of groundwater elevations prepared by the Los Angeles County Department of Public Works, Hydraulic/Water Conservation Division (LACDPW, 1995), and from compiled geotechnical and environmental borehole logs.

Depth to groundwater for the primary and secondary routes is shallowest in the vicinity of the Santa Clara River crossings (Figure 11). Along Avenue Scott, groundwater depths vary from 0 to 15 feet. Depth to groundwater becomes progressively deeper to the southeast along both routes, essentially below the depth of excavation (15 feet depth) where the two routes merge at Magic Mountain Parkway. Because the pipeline will be located on bridges that cross Santa Clara River, above the river channel, the areas most likely to have groundwater at the depth of pipeline excavation are those less than 5 feet depth shown on Figure 11 along Avenue Scott. In these areas shallow groundwater conditions may require dewatering during pipeline trenching.

4.0 GEOLOGIC HAZARDS

Because of the relative frequency of earthquakes in the Transverse Ranges, it is likely that during the design life of the proposed pipeline (50 or more years), an earthquake will occur of sufficient size that could potentially cause damage to the proposed pipeline. The effects of strong ground shaking, associated ground deformation, fault rupture, and potential tsunami inundation are of primary concern to the safe operations of the proposed pipeline and associated facilities. Secondary hazards intrinsic to geologic deposits and associated soils along the route include slope instability, expansive soils, and corrosion. Additional potential hazards include flooding and localized erosion that might expose and damage the proposed pipeline.

4.1 Fault Rupture

Ground surface displacement, or surface rupture, caused by an earthquake is a major consideration in the design of pipelines that cross active faults. Surface rupture occurs when movement on a fault deep within the earth breaks through to the surface. Most surface faulting is confined to a relatively narrow zone several feet to tens of feet wide, making avoidance (i.e., building setbacks) the common mitigation method. Fault rupture typically follows preexisting faults, which are zones of weakness. Specific geomorphic features commonly coincide with the locations of repeated fault-rupture. Thus, identification of active faults that might produce surface rupture requires: (1) location of existing faults and, (2) evaluation of the recency of activity on the faults. The most useful and direct method of evaluating fault activity is to document the youngest geologic unit faulted and the oldest unit that is not faulted to constrain the timing of the most recent surface offset on the fault.

The Alquist-Priolo Earthquake Fault Zone Act of 1972 was established by the California Legislature to mitigate the potential hazards of surface rupture associated with seismic activity. The Act requires the California Geological Survey (CGS) to evaluate and delineate active faults throughout the state. A fault or fault zone is considered active under the provisions of the Act if there is evidence of surface displacement within the last 11,000 years (Holocene time). Under the Alquist-Priolo Act, if faults are "sufficiently active" and "well-defined," they are zoned and construction along them is regulated. A fault is thought to be sufficiently active if one or more of its segments or strands show evidence of surface displacement during Holocene time. A fault is considered well-defined if its trace can be clearly identified by a trained geologist at the ground surface or in the shallow subsurface, using standard professional techniques, criteria, and judgment (Hart and Bryant, 1997).

The Center Road Pipeline routes and Line 225 Loop Pipeline routes appear to cross known active or potentially active faults that are capable of surface rupture. Thus, fault rupture is a direct concern to pipelines constructed along these routes. The Center Road Pipeline routes cross the Wright Road fault, a mapped Alquist-Priolo fault zone. The Line 225 Loop routes cross the eastern projection of the Holser fault, an unzoned but potentially active fault. The Line 225 Loop Pipeline routes are within 0.3 mile of the active San Gabriel fault (Table 1), but do not cross the fault. Below we discuss the Wright Road and Holser faults in more detail, along with the proposed pipeline crossings of these faults.

4.1.1 Wright Road Fault

The north-south trending Wright Road Fault is a 2.8-mile-long (4.5-km-long) fault mapped northwest of Camarillo within Ventura County, California. The fault is named for a west-facing, approximately 6-foot-high (~2-m-high) scarp that trends north-south across Wright Road (Treiman, 1997). The northern inferred extent of the Wright Road fault crosses the proposed Center Road Pipeline routes adjacent to Santa Clara Avenue (Figure 13).

Previous researchers have suggested that the Wright Road Fault is a tear fault at the western end of the Camarillo anticline (Price and Whitney, 1992; Leighton & Associates, 1993; Whitney and Gath, 1994). Treiman (1997) performed detailed analysis and discussion of the Wright Road Fault in Fault Evaluation Report 237 for the California Geological Survey. Treiman (1997) mapped the location of the Wright Road Fault based on tonal lineaments, tonal contrasts, vegetation lineaments, and relatively low scarps observed in historic aerial photos dating back to 1927. In addition to the tonal variations observed by Treiman (1997), the most convincing evidence suggesting the presence of the Wright Road Fault is the west-facing scarp within a young fan surface. Treiman (1997) observed other scarps possibly associated with the Wright Road Fault, but these scarps bound an edge of an elevated older alluvial surface.

As part of our review of the proposed Center Road Pipeline routes, WLA geologist Rick Ortiz reviewed aerial photographs available from the Fairchild Collection at Whittier College in Whittier, California. The aerial photos were taken between 1927 and 1961 and provide partial to complete coverage of the Wright Road fault. Review of the aerial photos confirmed the presence of tonal lineaments and tonal contrasts described by Treiman (1997). The main west-facing scarp was also observed in the oldest aerial photos (Flight C-104, Frames H14-15, 1927 and Flight C-1910, Frames 14-15, 1932) provided by the Fairchild Collection.

Although these features, in addition to the observations and conclusions presented by Treiman (1997), suggest the presence of the Wright Road Fault, other non-tectonic explanations for formation of the observed features are possible. Review of the aerial photos indicated that the location of the modern channel location has been highly variable during the last century. It is plausible to conclude the scarps found within the vicinity of Wright Road could have been formed during lateral channel migration of the Santa Clara River. The arcuate nature of the scarps also suggest a fluvial origin for these features. A modern day analog for the formation of these features by fluvial processes can be observed within the early aerial photos from the Fairchild Collection and currently upstream of the Wright Road area along the western and northern margin of South Mountain.

Currently, if active, the sense and amount of slip per event on the Wright Road fault is unknown. If the fault is a reverse fault, as implied by the west-side-down topographic expression, the pipeline might experience localized compression. However, based on the structural location of the Wright Road fault as a possible tear fault between the Camarillo, Springville, and Oakridge faults, it is unlikely that the fault will experience large surface displacements. More likely, the fault is not a primary source for earthquakes but rather serves to transfer slip between the Simi fault system (Camarillo and Springville faults) to the Oakridge fault. As such, displacement on the Wright Road fault likely is an order of magnitude less than that expected on the larger fault system, in the range of several inches to a few feet versus larger offset per event predicted for the major faults. Modern steel pipeline oriented at a high angle to the fault, as proposed for the Center Road Pipeline routes, likely can accommodate minor surface offsets on the Wright Road fault.

4.1.2 Holser Fault

The potentially active Holser Fault, or an associated fault, crosses the proposed primary and secondary Line 225 Loop Pipeline routes in Santa Clarita Valley (Figure 14). Although shown on geologic maps, the activity and location of the Holser fault is poorly constrained. The Holser fault extends eastward from Piru Creek to the Santa Clara River near Castaic Junction. The fault is mapped as a south-dipping (60 to 65 degrees) reverse fault based on multiple oil wells that penetrate the fault to depths greater than 4 km (Yeats et al., 1994). Because the Holser fault is not mapped or zoned by the State of California as a fault rupture hazard, and available studies are inconclusive on the location and activity of the fault, the fault rupture potential of the Holser fault was not evaluated for this study. However, there is no documented evidence of prior surface offset across the proposed routes and, therefore, the hazard likely is minimal.

4.2 Ground Shaking

Ground shaking is the earthquake effect that results in the vast majority of damage during large earthquakes. Strong shaking from an earthquake can cause landslides, ground lurching, and liquefaction. Structural damage from strong ground shaking may be accompanied by structural damage from other hazards including fire, releases of hazardous materials, or flood inundation as a result of dam or water tank failure.

In 2002, the U.S. Geological Survey (USGS) completed an update of the national seismic hazard maps that depict the probabilistic groundshaking hazard for the entire United States (Frankel et al., 2002). The hazard was calculated at a series of gridded locations (spaced 0.05 km apart) across the country using probabilistic seismic hazard analysis (PSHA) techniques. The USGS maps display contoured ground motion parameters (PGA and spectral accelerations) for a given probability of exceedance. The California Geological Survey (CGS, 2002) provides estimates of the range of peak ground accelerations (PGA) expected in the vicinity of the pipeline corridors based on probabilistic criteria of 10% chance of exceedance in 50 years, incorporating collaborative work with the USGS. These PGA estimates incorporate corrections for underlying alluvium conditions along the pipeline routes.

The Center Road Pipeline routes may experience between 50 to >70% PGA within a 475-year recurrence (10% in 50 years), with the greatest ground shaking likely in the northeastern portion of the proposed routes (Figure 12; CGS, 2002; Frankel et al., 2002). The Line 225 Loop Pipeline routes likely may experience 60 to 70% PGA within a 475-year recurrence (Figure 14; CGS, 1997; Frankel et al., 2002). Welded steel transmission pipe is highly resistant to traveling ground waves. The estimated levels of ground shaking are large enough to produce ground displacement due to liquefaction, differential settlement, and/or slope failure. The majority of the four pipeline routes are underlain by shallow groundwater and soils that are conducive to liquefaction. This condition, coupled with the proximity of the pipelines to faults capable of high ground acceleration makes the underlying soils prone to ground failure, including liquefaction and landsliding as defined by regulatory mapping by CGS (Figures 15 and 16).

4.3 Liquefaction Hazard

Liquefaction-related ground failure historically has caused extensive structural and lifeline damage in urbanized areas around the world. Recent examples of these effects include damage produced during the 1989 Loma Prieta, 1994 Northridge, 1995 Kobe, and 1999 Turkey earthquakes. These and other historical earthquakes show that the distribution of liquefaction-related damage is not random, but generally is restricted to recently alluviated areas that contain low-density, saturated, granular sediments.

Distinctive and unusual patterns of ground shaking and localized damage in the alluvial areas of coastal Ventura County have occurred during past earthquakes, as interpreted from historical reports (Weber, Jr., and Kiessling, 1976). Cracks and sand-boil craters were reported in Calleguas Creek following the offshore 1973 M5.9 Point Mugu earthquake (California Division of Mines and Geology, 1976). Liquefaction features including sand boils, lurch cracks, and "mud volcanoes" also were documented in Mugu Lagoon (Morton and Campbell, 1973). It is probable that widespread damage to buildings and other structures in Oxnard and the Point Mugu Naval Station caused by the 1973 earthquake were due in part to liquefaction and associated unstable soil conditions (CGS, 2002). More recently, during the Northridge earthquake, liquefaction occurred at the mouth of the Santa Clara River in Oxnard/Ventura, in Simi Valley, and along the Santa Clara River between Fillmore and Newhall (Barrows et al., 1995).

In the Valencia area, the Northridge earthquake caused concentrations of pipeline damage in Pico Canyon and near Newhall that may have been associated with liquefaction (Stewart and others, 1994; Hodgkinson and others, 1996; CGS, 1997). However, CGS (1997) noted that no conclusive evidence of liquefaction, such as sand boils, was identified in these areas and the depth to groundwater is greater than 60 feet. Based on available information, CGS (1997) concluded that the damage in these areas was not the result of liquefaction and the areas were not included in the liquefaction zones.

Extensive young gravel, sand, and silt deposits in the Oxnard Plain and along the Santa Clara River (Weber, Jr., et al., 1978), shallow groundwater (California State Water Resources Board, 1971), and the presence of nearby potentially active faults (Yeats et al., 1994; Dolan et al., 1995; Hitchcock et al., 2000a), indicate that parts of Ventura and Los Angeles Counties are particularly susceptible to liquefaction-related hazards. The proposed Center Road and Line 225 Loop Pipeline routes traverse areas of shallow groundwater and liquefiable deposits zoned by CGS as potentially susceptible to liquefaction during future earthquakes and mapped by William Lettis & Associates, Inc. (Hitchcock et al., 2000) as susceptible to liquefaction (Figures 15, 16, 17, and 18).

4.3.1 Liquefaction Susceptibility

The potential for liquefaction depends on both the susceptibility of a deposit to liquefy and the opportunity for ground motions to exceed a specified threshold level. Liquefaction susceptibility is the relative resistance of a deposit to loss of strength when subjected to ground shaking. Loss of soil strength can result in ground failures at the earth's surface. These failures, including localized ground settlement and lateral spreading, can cause significant property damage.

Physical properties of surficial deposits govern the degree of resistance to liquefaction during an earthquake. These properties include sediment grain-size distribution, density, cementation, saturation, and depth. Sediments that lack resistance to liquefaction (susceptible deposits) commonly include saturated young sediments that are sandy and loose. Sediments resistant to liquefaction include older surficial deposits that are dry or sufficiently dense.

4.3.2 Liquefaction Opportunity

Liquefaction opportunity is formally defined as the probabilistic estimate of expected ground shaking weighted according to the magnitude of the earthquake that contributes most to the seismic hazard at the site. Liquefaction features typically occur during long-duration, strong ground motion generally exceeding 0.15 g peak ground acceleration (PGA). These ground motions are produced by moderate to large magnitude earthquakes, generally exceeding M6.5. Historic and geologic evidence of large earthquakes in Ventura County, and evidence of past liquefaction during these earthquakes (Barrows et al., 1995), demonstrates that the opportunity exists to produce liquefaction in susceptible sediments in Ventura County.

PGA values of 0.5 to >0.7 g derived from ground shaking analyses by the USGS (Frankel et al., 2002) and CGS (1997, 2002) are used for the design level 10% exceedence in 50 years required in the Uniform Building Code (UBC, 2000) guidelines. These values are significantly higher than the PGA values required to initiate liquefaction in deposits present along the Center Road Pipeline routes.

4.3.3 Liquefaction Potential

Liquefaction potential of deposits along the proposed pipeline routes was assessed by analyzing Standard Penetration Test (SPT) data collected within borings compiled by William Lettis & Associates, Inc., in cooperation with the California Geological Survey, for the Oxnard Plain area (Hitchcock et al., 2000a).

Copies of the logs interpreted for this study are available upon request. The Standard Penetration Test (SPT) consists of driving a split tube soil sampler of standardized dimensions into the bottom of a drilled hole with a 140-pound hammer falling a distance of 30 inches onto the drill rods. The SPT blow count (N-count) is the number of hammer blows required to drive the sampler a distance of 12 inches. SPT N-count data provide a standard measure of the penetration resistance within a geologic deposit, and are commonly used as an index of density or grain packing. In general, the lower the N-count, the more loosely grains are packed, and the more susceptible the deposit is to liquefaction.

Standard Penetration Test (SPT) data from exploratory borings were analyzed using the Seed Simplified Approach (Seed and Idriss, 1971; Seed et al., 1985; Seed and Harder, 1990) to quantify the liquefaction susceptibility of the alluvial sediments. This method factors groundwater conditions, overburden loads, SPT-determined relative density, and estimated earthquake cyclic stress ratio. Analyses were performed for a specific earthquake scenario of magnitude M7.5. SPT blow count data were adjusted to standardized $N_1(60)$ values (Seed and Harder, 1990) using a proprietary spreadsheet, and compared to the predicted cyclic stress ratio (CSR) to evaluate what ground motion values (PGA) are required to produce liquefaction. In addition, the liquefaction analysis calculates soil resistance to liquefaction, expressed in terms of cyclic resistance ratio (CRR), based on SPT data, ground water level, soil density, moisture content, soil type, and sample depth. This procedure was used to establish potential peak ground acceleration triggering levels and factor of safety values for deposits present beneath the proposed pipeline route. Results are presented in Table 7 and discussed below.

Factors that control the susceptibility of sedimentary materials to liquefaction include: (1) geotechnical properties of the sediment, (2) depth to ground water, and (3) intensity and duration of strong ground shaking. Our susceptibility analysis suggests that some of the alluvial sediments will liquefy at ground-motion accelerations of 10% (or 0.1) PGA (Table 7).

4.3.4 Liquefaction Surface Effects

Liquefaction of subsurface sediments does not in itself pose a hazard or risk to buried pipelines. Liquefaction of surrounding deposits may cause a pipe to be uplifted due to buoyancy effects, but generally does not pose a rupture hazard for modern steel pipelines (O'Rourke and Liu, 1999). The primary hazard to a pipeline is from ground failures caused by liquefaction, including differential settlement and lateral spreads

Table 7. Liquefaction Susceptibility for Geologic Units along Center Road Pipeline Routes.

Geologic Unit	Description	Number of Borings	Ground Motion Threshold*	Historic Liquefaction	Depth to Groundwater			
					<5'	<10''	<20'	20'-40'
Qw, Qw1, Qw2	Historic Stream Wash Deposits	12	<0.1g	Yes	**VH**	**VH**	**H**	**M**
Qf	Historic Alluvial Fan Deposits	14	<0.1g	Yes	**VH**	**VH**	**H**	**M**
Qya2	Latest Holocene Valley Alluvial Deposits	10	<0.1g	Yes	**VH**	**VH**	**H**	**M**
Qyf2	Latest Holocene Valley Alluvial Fan Deposits	8	<0.2g	No	**H**	**H**	**M**	**M**
Qyf1	Holocene Valley Alluvial Fan Deposits	0	<0.3g	No	**M**	**M**	**M**	**M**
Qof	Pleistocene Alluvial Fan Deposits	0	>0.3g	No	**L**	**L**	**VL**	**VL**
Qoa	Pleistocene Undifferentiated Alluvial Deposits	0	>0.3g	No	**L**	**L**	**VL**	**VL**
Qoat2	Pleistocene Stream Terrace Deposits	0	>0.3g	No	**VL**	**VL**	**VL**	**VL**
B	Bedrock	0	NA	No	**VL**	**VL**	**VL**	**VL**

* Estimated PGA ground motion required to trigger liquefaction.
H = Liquefaction Susceptibility Rating (VH = Very High, H = High, M = Moderate, L = Low, VL = Very Low).

Lateral spreading on gently sloping ground generally is the most pervasive and damaging type of liquefaction-related ground failure (Bartlett and Youd, 1992; 1995). This type of failure involves lateral extension and fracturing of intact surficial material caused by liquefaction of a subjacent layer. Lateral spreads develop on gentle slopes, typically towards a free face (e.g., stream banks, canals, and arroyos), and may produce horizontal displacements of as much as tens of feet (Youd, 1978). Slope conditions along the proposed pipeline routes typically are very low (0.5 to 1.0 degrees), suggesting that potential lateral spreading, if it occurs, will consist of small displacements unlikely to damage the proposed modern steel pipelines.

Possible lateral spreading hazards may exist at stream and river crossings, depending on the conditions at the bridge and infrastructure that the pipeline utilizes at these crossings. The proposed Line 225 Loop Primary Pipeline route crosses the Santa Clara River along McBean Parkway Bridge and San Francisquito Creek along Avenue Scott Bridge. The pipeline will be attached to the underside of the existing open-girder bridges at McBean Parkway and Avenue Scott. The route also spans the South Fork of the Santa Clara River near the intersection of Magic Mountain Parkway and San Fernando Road, where the pipeline will be installed within the roadway through the existing bridge. At all bridge crossings, the groundwater level is at or below the deepest portion of the river channel. Therefore, most of sediments beneath the floodplain surface should be dry to a depth of the channel incision. In addition, analysis of available borings indicates that the cumulative thickness of liquefiable deposits along the Santa Clara River is very small and, thus, lateral spreading is unlikely to occur. This interpretation is supported by the absence of evidence of historic spreading along the Santa Clara River and absence of lateral spreading in the vicinity of the proposed crossing in the 1994 Northridge earthquake.

Differential settlement caused by liquefaction can impact buried pipelines (O'Rourke and Lane, 1989). Currently, there are two published methods for assessing amounts of settlement in clean sands (Tokimatsu and Seed, 1987; Ishihara and Yoshimine, 1992), both of which require detailed, site-specific subsurface geotechnical data to depths of 40 feet. These methods estimate that typical volumetric strains for clean sands range from 1 to 5% (Jones et al., 1994).

Based on these previous empirical studies, we estimate the amount of settlement that may be expected along the pipeline route. Our conservative approach to estimating the amount of settlement is to assume a 5% volumetric change in sandy sediments. We also assume that liquefaction occurs within about 60 to 70% of a saturated thickness of 30 to 45 feet of alluvium beneath the pipeline. Based on these parameters, we conservatively estimate that the maximum amount of liquefaction-induced settlement is likely to be less than 18 to 20 inches. This likely is a maximum value as the alluvium typically does not entirely consist of clean sands and probably is not completely saturated at, and below, the depth of the pipe.

This amount of settlement likely will not pose a hazard to the proposed pipelines, depending upon how and where settlement occurs along the pipeline. If the pipeline settles relatively uniformly, there will be very little differential settlement between any two points along the pipeline. However, differential settlement between geologic units, such as alluvium and bedrock, may result in as much as one foot of settlement over a very short distance. This type of phenomenon would be similar to ground deformation observed along the margins of Potrero Canyon during the 1994 Northridge earthquake. Although the differential settlement may result in extension of the pipeline, modern steel pipelines can withstand localized extension.

4.4 Ground Subsidence

Non-tectonic land subsidence can be induced by both natural and human phenomena. Natural soil subsidence can be caused by consolidation, hydrocompaction, and oxidation or dewatering of organic-rich soils. The most common cause of man-induced subsidence is the withdrawal of fluids; including oil, gas, and water.

A large portion of the Oxnard Plain has experienced subsidence due to groundwater withdrawal (City of Oxnard et al., 1980; California Division of Mines and Geology [CDMG], 1973). Records from 1968 show a dozen benchmarks that have settled 1 foot in a 15- to 20-year period. Up to 0.05 feet (0.01 to 0.02 m) of subsidence per year has occurred based on monitoring by the United States Coast and Geodetic Survey since 1930 (City of Oxnard et al., 1990). Subsidence likely will continue and the rate and amount of ground settlement could increase if there is an increase if there is an increase in the extraction of fluids from the area.

No local subsidence has been reported in the vicinity of the Line 225 Loop, within the City of Santa Clarita, due to groundwater or oil extraction (City of Santa Clarita General Plan, Safety Element, 1991). Santa Clarita is located over consolidated sediments that are not very prone to subsidence. The subsidence potential associated with groundwater or oil removal within the city is low.

Mitigation measures to prevent damage to pipelines and associated facilities from ground subsidence include appropriate foundation characterization and design. Because subsidence generally is regional, localized differential settlement sufficient to damage the proposed pipelines is not anticipated in either the Oxnard Plain or Santa Clarita Valley.

4.5 Slope Stability

Within Ventura and Los Angeles Counties, steep slopes and occasional intense storm conditions increase the potential for mudslides, landslides, and debris flows. In addition, wildfires may remove vegetation, increasing unstable slope conditions and the likelihood of debris/mudflow events. Slope failure can occur in the form of creep, slumps, large progressive translation or rotational failures, rockfall, or debris flows.

Landslides can occur during earthquakes, triggered by the strain induced in soil and rock by the ground shaking vibrations. During non-earthquake (static) conditions, slope failures occur most frequently during the rainy season when high groundwater conditions persist. Landslides occur most frequently during or following large storms and in years with significant precipitation.

Landslides are most likely to occur in areas where they have previously occurred (Nilsen and Turner, 1975). Landslide mapping, therefore, provides a basis for extimating the most likely locations for future slope failure. Our review of existing maps, including landslide inventory maps, confirmed that the proposed pipeline routes do not cross any identified active or recently active slope failures. Existing landslide hazards are minimal or nonexistent along most of the proposed routes because surface gradients are very gentle.

4.6 Tsunamis/Seiche

Tsunamis are waves generated by rapid displacement of a large volume of seawater, typically resulting from submarine vertical faulting, warping of the sea floor, volcanic eruptions, or large-scale submarine slides. As a tsunami approaches the shoreline, the wave height increases, resulting in potentially destructive onshore impacts. Historical records and recent field observations indicate that the severity of tsunami-generated damage depends on the type and size of the tsunami source, coastal topography, and the direction of the incoming waves. Hazards from tsunamis include: (1) runup where tsunami waves wash ashore at heights above normal wave action, and (2) strong currents that can cause localized coastal erosion.

The only historic tsunami to cause significant damage and loss of life along the California coast occurred as a result of the 1964 Alaska earthquake. Several smaller tsunamis have been recorded along the Ventura coastline over the past 200 years, each generally accounting for run-up wave heights of less than 3 to 4 feet (McCulloch, 1985). However, the potential exists for a future major tsunami that might inundate southern portions of the Center Road Pipeline routes. Locally generated tsunamis could result from significant displacement of submarine faults or from submarine slides. A preliminary appraisal of the potential for locally generated tsunamis suggests that wave run-up heights as great as 12 to 18 feet could be caused by sea-floor faulting in the Santa Barbara Channel (McCulloch, 1985).

Seiches are oscillations in an enclosed body of water, such as a lake, that may be caused by an earthquake. Most seiches are created when landslides fall into a body of water and displace a large volume of water. There are no enclosed bodies of water along the proposed routes and thus mitigation for seiches is not required.

Because the pipeline will be buried, and only the southern portion of the proposed Center Road Pipeline routes are within the tsunami zone, mitigation measures likely are not required to prevent damage to pipelines and associated facilities from tsunami inundation.

4.7 Flooding and Erosion Hazards

Flooding typically is not a hazard for buried pipelines unless localized erosion and stream scour occurs. Local drainage floods with associated scour may occur outside of recognized drainage channels or delineated floodplains due to a combination of locally heavy precipitation, a lack of infiltration, inadequate facilities for drainage and stormwater conveyance, and increased surface runoff.

The FEMA regulatory standard for floods in the United States is the base flood, or "100-year flood", that has a 1 percent chance of occurring in any particular year. The 100-year flood zone, based on the available FEMA flood maps, intersects a relatively small portion of the pipeline corridor (Figures 19 and 20). Minor flooding is possible along the Center Road Pipeline routes north of Highway 101, principally due to ponding of floodwaters (Figure 19). More extensive flooding may occur along the Santa Clara River in Santa Clarita Valley (Figure 20). Potential erosion hazards to pipelines may exist where pipelines are buried beneath, or extend across, active stream channels or topographic swales. Pipeline exposure, although unlikely along the proposed routes, may occur as a result of streambed scour or bank erosion, either from individual storms, or from long-term, gradual channel scouring or widening.

4.8 Expansive and Collapsible Soils

Expansive soils possess "shrink-swell" behavior. Shrink-swell is the cyclic change in volume (expansion and contraction) that occurs in fine-grained sediments from the process of wetting and drying. Under the existing regulatory framework of both the Public Works Agency and the Building and Safety Department of Ventura County, an expansive soil hazard is considered to exist where soils with an expansion index greater than 20 are present. Typically the expansion index of a soil is directly correlative to the amount of clay in the soil, with a high clay percentage resulting in a high expansion index (Edwards et al., 1970).

Overall, the shrink-swell potential of soils along the proposed Center Road and Line 225 Loop Pipeline routes is moderate, with portions (2% to 5%) of the Center Road Pipeline routes having a high shrink-swell potential (Table 8). Potentially expansive soils present along the proposed routes include the Rincon soil units (RcC & RcE3, Figure 6). Several soils have a moderate potential for expansivity, including the Camarillo (Cd, Cc, Ce), the Hueneme (Hn, Hm), the Pacheco (PA), the Huerhuero (HuB, HuD2), the Mocho (MoA), and the Sorrento (Swa, Swc) soil units (Figure 6). Soil expansion is not a significant hazard for modern coated steel pipelines, such as those proposed for the Center Road and Line 225 Loop Pipelines.

Collapsible soils are soils that contain voids, or weak calcareous and/or argillic cements that dissolve and allow settlement when brought in contact with water. Hydrocompaction can range from fractions of an inch to several feet and often results in differential settlement over short distances. Collapsible soils are typically limited to true loess, clayey loose sands, loose sands cemented by soluble salts, windblown silts, and flash-flood deposits. Along the proposed pipeline routes, in Oxnard and Santa Clarita Valley, no such collapsible deposits were identified. Since the proposed routes generally are underlain by granular to fine-grained soils with no history of hydrocompaction or localized collapse, the potential for impacts from collapsible soils along the proposed routes is considered low.

4.9 Corrosive Soils

Potential external corrosion hazards to pipeline systems are dependent in part on the conductivity of the ground and the corrosive nature of soils in which the pipeline is buried. Corrosivity of soils is dependent on soil texture, soil pH, moisture content, and geochemical composition of fluids within the soil. These factors, in turn, are influenced by the physical and mineralogic composition of soils. Soil composition often is directly derived from the characteristics of the underlying geologic deposits on which they develop. Silty, loamy and clayey soils tend to be among the more corrosive potential soils in contrast to granular soils (sands and gravels). In addition, the topography of the land, depth to groundwater, and native vegetation all influence the soil corrosivity potential.

Table 8. Summary Table of Potentially Expansive Soils along All Pipeline Routes.

Center Road Pipeline Routes				
Route	**Shrink-Swell Potential**	**Total Feet**	**Total Miles**	**Percent of Route**
Proposed Route	High	1,095	0.207	4.75%
	Moderate	15,230	2.88	66%
	Low	6,715	2.88	29.1%
Center Road Alternative 1 Route	High	746	0.14	3.4%
	Moderate	15,051	2.85	69.8%
	Low	5,760	1.09	26.7%
Center Road Alternative 2 Route	High	746	0.14	4.1%
	Moderate	8,401	1.59	46.6%
	Low	8,867	1.59	49.2%
Casper Road Route	Moderate	1,086	0.205	47.4%
	Low	1,205	0.228	52.6%
Arnold Road Route	Moderate	1,608	0.305	69.7%
	Low	698	0.132	30.2%
Gonzales Road Route	High	746	0.14	8.7%
	Moderate	2,678	0.507	31.5%
	Low	5,075	0.96	59.7%

Line 225 Pipeline Loop Routes				
Route	**Shrink-Swell Potential**	**Total Feet**	**Total Miles**	**Percent of Route**
Primary	Moderate	10,654	2	27%
	Low	23,929	4.5	60%
Alternative	Moderate	31,507	6.0	58%
	Low	20,809	3.9	38%
	Other	2,383	0.5	4%

Although soil corrosivity can exist within a broad range of soil conditions, the extent of acidity or alkalinity of a soil, as expressed by pH, directly influences corrosion susceptibility. Soils whose pHs generally are less than 9.0 have been found to be among the more corrosive soils (Romanoff, 1997). Typically soils with a pH of 0.0 to 4.0 are acidic and, where saturated, can serve as a corrosive electrolyte. Soils with a more neutral pH of 6.5 to 7.5 and low redox conditions are optimum for sulfate reduction by bacteria, which can cause localized corrosion. Soil resistivity also has a strong influence on the corrosion rate. Generally, the higher the resistivity, the lower the corrosion rate. Soil resistivity arises from a number of factors, but fine-grained soils (silts, loams, clays) typically have the lowest resistivities and thus the greatest corrosion susceptibility.

Based on compilation of the soils data, most of the Center Road Pipeline routes are mapped within soils with a high corrosion potential (Figure 6; Table 9). The soils mapped along the Primary and Secondary Line 225 Loop Pipeline routes, have more variable corrosion potential, ranging from low (28-41%), to moderate (19-28%), and high (20-31%) as shown in Figure 7 and in Table 9.

Table 9. Summary Table of Steel (uncoated) Corrosion Hazard along All Pipeline Routes.

Center Road Pipeline Routes				
Route	**Steel Corrosion**	**Total Feet**	**Total Miles**	**Percent of Total Pipe**
Proposed Route	High	23,040	4.28	98.1%
	Low	226	0.04	1.0%
	Other	205	0.038	0.9%
Center Road Alternative 1 Route	High	21,331	4.08	99%
	Low	226	0.04	1.0%
	Other	176	0.8	0.03%
Center Road Alternative 2 Route	High	17,654	3.34	98%
	Low	226	0.04	1.3%
	Other	134	0.025	0.7%
Casper Road Route	High	2,291	0.43	100%
Arnold Road Route	High	2,306	0.436	100%
Gonzales Road Route	High	8,139	1.54	95.8%
	Low	226	0.042	2.7%
	Other	134	0.025	1.6%

Line 225 Loop Pipeline Routes				
Route	**Steel Corrosion**	**Total Feet**	**Total Miles**	**Percent of Total Pipe**
Primary	High	12,506	2.4	31%
	Moderate	10,275	1.9	25%
	Low	16,683	3.2	41%
	Other	328	0.1	<1.0%
Alternative	High	11,480	2.2	20%
	Moderate	10,277	1.9	19%
	Low	31,992	6.1	28%
	Other	622	0.1	<1.0%
	Unclassified	328	0.1	<1.0%

Due to the presence of shallow groundwater and highly corrosive soils along the Center Road Pipeline routes, and moderate to high corrosion potential present along the Line 225 Loop Pipeline routes, are present along the proposed routes. However, modern coated steel pipelines constructed to SoCalGas standards are much less vulnerable to corrosion than uncoated steel used in SCS soil hazard evaluation.

5.0 PIPELINE CONSTRUCTABILITY

Excavation characteristics (including suitability of native material for reuse as backfill) are discussed below.

5.1 Trench Stability

The texture and consistency of soils and bedrock along the pipeline route should permit standard cut-and-cover trenching operations. Materials along the route can be excavated using standard pipeline trenching techniques. However, the fine-grained texture and relatively soft consistency of some silty materials may require shoring to maintain the trench excavations.

5.2 Potential Dewatering Requirements

Potential dewatering of pipeline excavations may be required, particularly in areas of shallow groundwater. Significant long-term adverse effects arising from dewatering are considered unlikely. Hydrologic changes could result from trench backfilling if choices of backfill material and methods of emplacement alter surface and subsurface flow. For example, the pipeline backfill materials (such as gravel or coarse-texture non-native fill) may be more or less permeable than native materials. Local settlement of non-engineered backfill could create ditches along the pipeline, causing interception and detention of groundwater or surface water.

5.3 Backfill Requirements

Soils along the proposed pipeline routes include potential expansive soils (Edwards, 1970; Woodruff et al., 1970). Although these soils are expansive, the pipeline and related structures will be constructed in accordance with applicable engineering standards and building codes.

6.0 SUMMARY AND RECOMMENDATIONS

Because of the relative frequency of earthquakes in the vicinity of the proposed pipeline routes, it is likely that during the design life of the proposed pipeline (within the next 50 years), a moderate to large earthquake will occur in the region traversed by the pipelines. Modern welded steel transmission pipe is highly resistant to traveling ground waves and direct damage from possible strong ground shaking associated with a moderate to large earthquake is unlikely. In addition, the absence of mapped active landslides along the proposed pipeline routes and relatively flat topography significantly reduces the possibility of permanent ground displacements during future earthquakes sufficient to damage or rupture the modern coated steel pipelines that will be buried along the proposed routes. Similarly, regional subsidence due to groundwater withdrawal or earthquake-induced settlement is a minimal hazard to the proposed pipelines as historical and predicted ground surface settlement is not sufficiently localized, or large enough, to damage buried pipelines.

Pipelines along the Line 225 Loop Pipeline routes will be placed on existing bridges that span San Francisquito Creek and the Santa Clara River. The pipelines will be placed above the active stream channel and floodplains and, therefore, are unlikely to be exposed to, or impacted by, flooding or localized stream scour at these crossings. In addition, groundwater at the bridge crossings is sufficiently deep and the deposits sufficiently consolidated that lateral spreading at the stream and river crossings is unlikely. Therefore, failure of the bridges, and the attached pipelines, due to liquefaction-induced lateral spreading during future earthquakes is unlikely.

The Center Road and Line 225 Loop Pipeline routes cross potentially active faults that have the potential of producing surface rupture across the proposed pipeline routes. The Center Road Pipeline routes cross the Wright Road fault, delineated by the State of California as Alquist-Priolo fault zone that contains a potentially Holocene active fault (Treiman, 1997). The presence of the Wright Road fault has not been confirmed by detailed subsurface studies or paleoseismic trenching. However, if present, the fault likely is a secondary fault capable only of minor offset during large earthquakes on nearby major fault systems.

Although the style and amount of potential surface offset on the Wright Road fault is unknown, the pipeline routes cross the fault zone at a sufficiently large angle to withstand the possible offset associated with secondary surface rupture on the fault. The Line 225 Loop Pipeline routes cross the eastern projection of the Holser fault, an unzoned but potentially active fault. The Holser fault is poorly located but there is no apparent evidence of previous surface rupture across the proposed pipeline routes and, thus, associated fault offset likely is not a significant hazard to the proposed pipelines.

Based on available soils data, the Center Road Pipeline routes are within soils with a high corrosion potential and moderate to high potential for shrink-swell. Soils mapped along the Line 225 Loop Pipeline routes are less corrosive and potentially expansive. The potential impact of corrosive and expansive soils along the proposed pipeline routes, therefore, is moderate to low, and unlikely to significantly impact modern coated steel pipelines proposed for the project.

7.0 REFERENCES

ASTM, 1996, Annual book of ASTM Standards; Soil and Rock (I&II): American Society for Testing Material, v. 4.08-4.09.

Barminski, R.F., Jr., Barminski, J.R., Barminski, M.J. and Bittman, Steve, 1994, Liquefaction-related ground failure at the mouth of the Santa Clara River, Ventura County, California from the 1994 Northridge earthquake: American Association Petroleum Geologists, Pacific Section, 69th Annual Meeting Ventura, California, Addendum to Program and Abstracts, Ventura, California, p. 49.

Barrows, A.G., Irvine, P.J. and Tan, S.S., 1995, Geologic surface effects triggered by the Northridge earthquake, in Woods, Mary C. and Seiple, W. Ray, editors, The Northridge, California, earthquake of 17 January 1994: California Department of Conservation, Division of Mines and Geology Special Publication 116, p. 65-88.

Barlett, S.G., and Youd, T.L., 1992, Empirical analysis of horizontal ground displacement generated by liquefaction-induced lateral spread: NCEER, Technical Report NCEER-92-0021.

California Department of Water Resources, 1971, Seawater intrusion: Aquitards in the coastal ground water basin of the Oxnard Plain, Ventura County: Department of Water Resources Bulletin 63-4, 569 p.

California Department of Conservation, Division of Mines and Geology, 2000, Recommended criteria for delineating seismic hazard zones in California, Special Publication 118, 12 p.

California Department of Conservation, Division of Mines and Geology, 1997, Guidelines for evaluating and mitigating seismic hazards in California, Special Publication 117, 74 p.

California Department of Public Works (DPW), 1933, Ventura County Investigation: Division of Water Resources Bulletin 46, 244 p.

California Department of Water Resources, 1971, Seawater intrusion: Aquitards in the coastal ground water basin of the Oxnard Plain, Ventura County: Department of Water Resources Bulletin 63-4, 569 p.

California Division of Mines and Geology, 1996, Probabilistic Seismic Hazard Assessment for the State of California, CDMG Open-File Report 96-08/USGS Open-File Report 96-706.

California Division of Mines and Geology, 1976, Seismic hazards study of Ventura County, California: Open File Report 76-5 LA, 396 p., map scale 1:48,000.

California Geological Survey (CGS), 1997a, Guidelines for evaluating and mitigating seismic hazards in California: CGS Special Publication 117.

California Geological Survey (CGS), 1997b, Seismic hazard evaluation of the Newhall 7.5-minute quadrangle, Los Angeles County, California: CGS Open-File-Report 97-11.

California Geological Survey (CGS), 1998, Maps of known active fault near-source zones in California and adjacent portions of Nevada: International Conference of Building Officials.

California Geological Survey (CGS), 2002, Seismic hazard zone report, Oxnard 7.5-minute quadrangle, Ventura, California: Seismic Hazard Report 052.

Cao, T., Bryant, W.A., Rowshandei, B., Branum, D., and Willis, C.J., 2003, The Revised 2002 California Probabilistic Seismic Hazard Maps June 2003, California Geological Survey, http://www.consrv.ca.gov/cgs/rghm/psha/fault_parameters/pdf/2002_CA_Hazard_Maps.pdf.

City of Oxnard, 1990, City of Oxnard 2020 General Plan.

City of Santa Clarita, 1991, Safety Element of the General Plan.

Cramer, C.H. and Petersen, M.D., 1996, Predominant seismic source distance and magnitude maps for Los Angeles, Orange, and Ventura counties, California: Bulletin of Seismological Society of America, v. 86, no. 5, p. 1,645-1,649.

Densmore, J.N., 1996, Lithologic and ground-water data for monitoring wells in the Santa Clara-Calleguas ground-water basin, Ventura County, California, 1989-95: U.S. Geological Survey Open-File Report 96-120, 177 p.

Dibblee, T.W., Jr., 1996, Geologic map of the Newhall Quadrangle, Los Angeles County, California: Dibblee Geological Foundation Map DF # 56, scale 1:24,000.

Dibblee, Thomas W., Jr, and Ehrenspeck, Helmut, E., 1990, Geologic Map of the Camarillo and Newbury Park Quadrangles, Ventura County, California: Dibblee Foundation Map DF-28, scale 1:24,000.

Dolan, J.F., Sieh, K., and T.K. Rockwell, 2000, Late Quaternary activity and seismic potential of the Santa Monica fault system, Los Angeles: California: Geol. Soc. Am. Bull. 112, p. 1559-1581.

Dolan, J.F., Sieh, K., Rockwell, T.K., Yeats, R.S., Shaw, J., Suppe, J., Huftile, G.J., and Gath, E.M., 1995, Prospects for larger or more frequent earthquakes in the LA Metro. Region: Science, v. 267, p. 199-204.Edwards, R.D., Rabey, D. F., and Kover, R.W., 1970, Soil Survey Ventura Area, California: U.S. Department of Agriculture, Soil Conservation Service, 151 p.

Ellsworth, 1990, Earthquake history, 1769-1989, in The San Andreas Fault System, California, ed. Wallace, R.E.: U.S. Geological Survey Professional Paper 1515, p. 153-188.

Frankel, A., C. Mueller, S. Harmsen, R. Wesson, E. Leyendecker, F. Klein, T. Barnhard, D. Perkins, N. Dickman, S. Hanson, and M. Hopper, 2000, U.S. Geological Survey National Seismic Hazard Maps, Earthquake Spectra, v. 16, p. 1-19.

Frankel, A., and ten other authors, 2002, Documentation for the 2002 Update of the National Seismic Hazard Maps: U.S. Geological Survey Open-File Report 02-420.

Hitchcock, C.S., Lindvall, S.C., Helms, J.D., Randolph, C.E., Weaver, K.D., and Lettis, W.R., 2000a, Liquefaction hazard mapping, Ventura County, California: Final Technical Report, U.S. Geological Survey, Award 99-HQ-GR-0117, 21 p. 4 plates.

Hitchcock, C.S., Lindvall, S.C., Lettis, W.R., Helms, J.G., Randolph, C., Weaver, K., and Kada, Lynne, 2000b, Liquefaction Hazard Mapping, Ventura County, California: Earthquake Engineering Research Institute, 6th International Conference on Seismic Zonation.

Hodgkinson, K.M., Stein, R.S., Hudnut, K.W., Satalich, Jay and Richards, H.H., 1996, Damage and restoration of geodetic infrastructure caused by the 1994 Northridge, California, earthquake: U.S. Geological Survey Open-File Report 96-517.

Idriss, I.M., 1991, Selection of earthquake ground motions at rock sites: Report prepared for the Structures Division, Building and Fire Research Laboratory, National Institute of Standards and Technology, Department of Civil Engineering, University of California, Davis, California, 34 p.

Ishihara, K., and Y. Yoshimine, 1992, Evaluation of settlement in sand deposits following liquefaction during earthquakes: Soils and Foundations, 32, p. 173-188.

Jones, C.F., T.L. Youd, and M.A. Mabey, 1994, Liquefaction hazard maps for the Portland, Oregon quadrangle, Proceedings of the Fifth U.S. National Conference on Earthquake Engineering, IV, p. 209-218.

Jennings, C.W., 1994, Fault activity map of California and adjacent areas with locations and ages of recent volcanic eruptions: California Division of Mines and Geology, Geologic Data Map No. 6, map scale 1:750,000.

LACDPW, 1995, Santa Clarita Ground-Water Contours, separate maps for the fall of each year from 1945 through 1995: Los Angeles County Department of Public Works.

Lander, J.F., Lockridge, P.A., and Kozuch, M.J., 1993, Tsunamis affecting the west coast of the United States 1806-1992: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, NGDC Key to Geophysical Records Documentation No. 29, 242 p.

McCulloch, D.S., 1985, Evaluating Tsunami Potential, *in* Ziony, J.I. (ed.), Evaluating Earthquake Hazards in the Los Angeles Region – An Earth-Science Perspective: U.S. Geological Survey Professional Paper 1360, p. 375-413.

Mualchin, L. and A.L. Jones, 1992, Peak acceleration from maximum credible earthquakes in California (rock and stiff soil sites): Division of Mines and Geology Open-File Report 92-1, California Department of Conservation, Division of Mines and Geology, Sacramento, California.

Morton, D.M. and Campbell, R.H., 1973, Some features produced by the earthquake of 21 February 1973, near Point Mugu, California: California Geology, v. 26, no. 12, p. 287-290.

O'Rourke, T.D., and P.A. Lane, 1989, Liquefaction hazards and their effects on buried pipelines, National Center for Earthquake Engineering Research Technical Report NCEER-89-0007.

O'Rourke, M.J., and X. Liu, 1999, Response of buried pipelines subject to earthquake effects: Multidiscilinary Center for Earthquake Engineering Research, MCEER Monograph No. 3.

O'Rourke, T.D. and M.C. Palmer, 1996, Earthquake Performance of Gas Transmission Pipelines: Earthquake Spectra, v. 12, no. 3, p. 493-527.

Real, et. al. 1978, Earthquake Epicenter Map of California, showing events from 1900 through 1974 equal to or greater than magnitude 4.0 or intensity V: California Division of Mines and Geology, Map Sheet 39.

Robson, S.G., 1972, Water-Resources Investigation using analog model techniques in the Saugus-Newhall Area, Los Angeles County, California: U.S. Geological Survey Open File Report, 58 p.

Romanoff, Melvin, "Underground Corrosion," Published by National Association of Corrosion Engineers (republished from National Bureau of Standards Circular 579), Houston, TX, 19-9.

Ross, et al., 2004, Comments on Potential Geologic and Seismic Hazards affecting Coastal Ventura County, California: U.S. Geological Survey Open-File Report 2004-1286.

Seed, H.B., 1987, Design problems in soil liquefaction: Journal of the Geotechnical Engineering Division, ASCE, 113, p. 827-845.

Seed, H.B., and Idriss, I.M., 1971, Simplified procedure for evaluating soil liquefaction potential: Proceeding of the American Society of Civil Engineers: Journal of the Soil Mechanics and Foundations Division, v. 93, no. SM9, p. 1249-1273.

Seed, H.B., and Idriss, I.M., 1982, Ground motions and soil liquefaction during earthquakes: Earthquake Engineering Research Institute, Engineering Monograph v. 5, 134 p.

Seed, H.B., Idriss, I.M., and Arango, I., 1983, Evaluation of liquefaction potential using field performance data: American Society of Civil Engineers, Journal of Geotechnical Engineering, v. 109, no. 3, p. 458-482.

Seed, H.B., Tokimatsu, K., Harder, L.F., and Chung, R.M., 1985, Influence of SPT procedures in soil liquefaction resistance evaluations: Journal of Geotechnical Engineering, ASCE, v. 111, no. 12, p. 1425-1445.

Seed, R.B., and Harder, L.F., 1990, SPT-based analysis of cyclic pore pressure generation and undrained residual strength, *in* Duncan, M.J., editor, H. Bolton Seed Memorial Symposium Proceedings, May, 1990: BiTech Publishers, Vancouver, B.C., Canada, p. 351-376.

Slade, Richard C. & Associates, LLC, 2002, 2001 Update Report, Hydrogeologic Conditions in the Alluvial and Saugus Formation Aquifer Systems, prepared for Santa Clarita Valley Water Purveyors.

Slade, Richard C. & Associates, LLC, 1986, Hydrogeologic Investigation of Perennial Yield and Artificial Recharge Potential of the Alluvial Sediments in the Santa Clarita River Valley of Los Angeles County, California, vols. I and II, prepared for Upper Santa Clara Water Committee.

Sprotte, E.C. and J.A. Johnson, 1976, Investigation of Potential Differential Settlement and Potential Liquefaction of Holocene Sediments Due to Seismically Induced Ground Shaking, Oxnard Plain Area, Ventura County, California, *in* California Division of Mines and Geology, 1976; Special Report - Seismic Hazards Study of Ventura County, California, California Division of Mines and Geology Open-File Report 76-5 LA.

Tinsley, J.C., Youd, T.L., Perkins, D.M., and Chen, A.T.F., 1985, Evaluating liquefaction potential, *in* Ziony, J.I., ed., Evaluating earthquake hazards in the Los Angeles region-An earth-science perspective: U.S. Geological Survey Professional Paper 1360, p. 263-315.

Tokimatsu, K., and Seed, H.B., 1987, Evaluation of settlement of sands due to earthquake shaking: Journal of the Geotechnical Engineering Division, ASCE, v. 113, p. 861-878.

Toppazada, T., Branum, D., Petersen, M., Hallstrom, C., Cramer, C., and Reichle,et al., 2000, Epicenters of and Areas Damaged by M>=5 California Earthquakes, 1800-1999: California Division of Mines and Geology, Map Sheet 49, scale 1:1,000,000.

Townley, S.D., 1939, Earthquakes in California, 1769 to 1928: Bulletin of the Seismological Society of America, v. 29, no. 1, p. 21-252.

Treiman, J.A., 1997, Springville, Camarillo and related faults in the Camarillo and Santa Paula quadrangles, Ventura County, California: California Division of Mines and Geology Fault Evaluation Report FER-237, 21p.

Treiman, J.A., 1986, Landslide hazards in the west half of the Newhall Quadrangle, Los Angeles County, California: California Department of Conservation, Division of Mines and Geology Open-File Report 86-6, scale 1:24,000.

Treiman, J.A., 1987, Landslide hazards in the east half of the Newhall Quadrangle, Los Angeles County, California: California Department of Conservation, Division of Mines and Geology Open-File Report 86-16, scale 1:24,000.

Turner, J.M. 1975, Aquifer delineation in the Oxnard-Calleguas area, Ventura County: Ventura County Department of Public Works Flood Control District Water Resources Management Study, 45 p.

Turner, J.M. and Mukae, M.M., 1975, Effective base of fresh water reservoir in the Oxnard-Calleguas area, Ventura County: Ventura County Department of Public Works Flood Control District Water Resources Management Study, 45 p.

Weber, F.H., Jr., Cleveland, J.E., Kahle, J.E., Kiessling, E.W., Miller, R.V., Mills, M.F. and Morton, D.M., 1973, Geology and mineral resources study of southern Ventura County, California: California Division of Mines and Geology Preliminary Report 14, 102 p., map scale 1:48,000.

Weber, F.H., Jr., and E.W. Kiessling, 1976, General Features of Seismic Hazards of Ventura County, California, *in* California Division of Mines and Geology, 1976; Special Report - Seismic Hazards Study of Ventura County, California. California Division of Mines and Geology Open File Report 76-5 LA.

Weber, F.H. Jr., 1982, Geology and geomorphology along the San Gabriel Fault Zone, Los Angeles and Ventura Counties, California: California Department of Conservation, Division of Mines and Geology Open-File Report 82-2, 157 p., map scale 1:24,000.

Wells, D.W., and K.J. Coppersmith, 1994, New empirical relationships among magnitude, rupture length, rupture width, rupture area, and surface displacement: Bulletin Seismological Society of America, 84, p. 974-1002.

Winterer, E.L. and Durham, D.L., 1962, Geology of southeastern Ventura Basin, Los Angeles County, California: U.S. Geological Survey Professional Paper 334-H, p. 275-366.

Woodruff, G.A., McCoy, W.J, and Sheldon, W.B., 1970, Soil Survey Antelope Lope Valley Area, California: U.S. Department of Agriculture, Soil Conservation Service, 187 p.

Yeats, R.S., Huftile, G.J. and Stitt, L.T., 1994, Late Cenozoic tectonics of the East Ventura Basin, Transverse Ranges, California: American Association Petroleum Geologists Bulletin, v. 78, no. 7, p. 1040-1074.Yerkes, R.F. and Campbell, R.H., 1995, Preliminary geologic map of the Newhall 7.5' Quadrangle, southern California: U.S. Geological Survey Open-File Report 95-503, scale 1:24,000.

Youd, T.L., 1973, Liquefaction, flow and associated ground failure: U.S. Geological Survey Circular 688, 12 p.

Youd, T.L., 1978, Major Cause of earthquake damage is ground failure: Civil Engineering, ASCE, 48, p. 47-51.

Ziony, J.I., ed. 1985, Evaluating Earthquake Hazards in the Los Angeles Region-An Earth Science Perspective: U.S. Geological Survey Professional Paper 1360.